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TRANSACTIONS OF THE NORFOLK & NORWICH NATURALISTS' SOCIETY

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TRANSACTIONS OF THE NORFOLK AND NORWICH NATURALISTS' SOCIETY

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WILDLIFE 2000

During its 125th anniversary celebrations, the Norfolk and Norwich Naturalists' Society announced its intention to document the wildlife of Norfolk for the start of the new millennium in a project called **Wildlife 2000.** In practical terms the project was launched in May 1995 when representatives of the Society, English Nature, Norfolk Wildlife Trust and the Castle Museum met and agreed to share this common vision.

Sir Thomas Browne has given us a fascinating glimpse of seventeenth century wildlife in the County of Norfolk. He writes of bustards, storks, ravens and kites; salmon and otters; and the mole cricket which he describes as common in "fenny places.... and dunghills and churchyards in this citty."

Nineteenth century records of the mole cricket from Castle Acre and Stoke Holy Cross suggest a lingering presence for this species in river flood plains across the county, but we are left tantalisingly ignorant of its historic distribution. How widespread was it, how abundant where it did exist, and until how recently did it survive?

Wildlife 2000 is a project designed to ensure that twenty first century naturalists will have the answers to the equivalent questions they might ask about our flora and fauna, as they approach the end of their own century.

Wildlife 2000 seeks to create a "time capsule" which will preserve our knowledge of the countryside, and what could be found in it at the start of the third millennium. The project is not just concerned with nature reserves and rare species, but seeks to give an accurate account of the wider countryside and the commoner species which abound within it.

Just as the mole cricket was common in Thomas Browne's day but is now lost, so any other creature or plant which we take for granted could become rare or extinct over the next century. By documenting the wildlife heritage which we pass into the care of the twenty first century, those who come after us may be in a better position to preserve and protect that legacy.

In this issue of the *Transactions* of the Norfolk and Norwich Naturalists' Society four papers reflect the aims of the **Wildlife 2000** project. In his Presidential Address Brian Wheeler examines the fens of Norfolk as the century comes to its close. In the first part, published in this edition of the *Transactions*, he looks at the valleyhead fens from both the ecological and the historical perspectives. He stresses the need to establish causes of change at individual sites and to offer management strategies for the future. Michael Jackson provides an overview of the macroinvertebrates of the littoral zone of the Norfolk Broads in the closing years of the 20th C. He compares these with earlier surveys and discusses some of the causal factors bringing about change. Jane Harris describes the vegetation and land-use of the ronds of the Broadland rivers and Keith Clarke extends this theme by examining the diatoms and deposits of the ronds of the Waveney.

WILDLIFE 2000

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WILDLIFE 2000

THE FENS OF NORFOLK: AN ECOLOGICAL AND HISTORICAL PERSPECTIVE. I. THE VALLEYHEAD FENS

THE PRESIDENTIAL ADDRESS DELIVERED TO THE SOCIETY IN MARCH 1999

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Introduction

No other area of comparable size in Britain supports the number and diversity of fens that are found in Norfolk. The FENBASE database (Wheeler, 1998) currently lists 142 fen 'sites' for Norfolk, from which have been recorded a total of 475 plant species. Of these, some 203 are particularly characteristic of wetlands and 34 are considered to be rare (Wheeler, 1988). 72 of these 'sites' have important fen interest and are included within designated Sites of Special Scientific Interest, based around individual fen sites or clusters of sites.

The Norfolk fens can be subdivided, very broadly, into two main types based upon the topographical situation in which they occur: valleyhead fens and floodplain fens. There are transitions between these categories and a small number of sites do not fit neatly into either, but they form a useful conceptual basis for considering the fen resource of Norfolk. In Norfolk, a major component of the water supply to the valleyhead fens is invariably groundwater discharge (springs and seepages) whereas most fens on floodplains receive some water from their adjoining watercourses, either by overbank flooding or by penetration through networks of dykes dug into the fens. However, some floodplain fens also receive groundwater inputs, usually at the margins, and in one or two cases (e.g. Upton Fen, which no longer has direct connection to the river) this nowadays constitutes their principal source of telluric water.

This contribution is not intended to provide a comprehensive review of the fen resource of Norfolk, nor of the ecology of the fens. Rather, it touches on a

number of topics that are relevant to understanding the character of the Norfolk fens and offers a perspective in which their conservational requirements can be assessed. This paper will mainly consider the valleyhead fens. Floodplain fens, including most of Broadland, will form the focus of a subsequent contribution.

THE VALLEYHEAD FENS

The concept of valleyhead fens

The useful term 'valleyhead fens' was introduced by Fojt (1990) to include wetlands that had been variously known as 'headwater fens' (Haslam 1965) and 'valley fens' (Wheeler 1984). As is suggested by their name, they occupy the headwaters of small tributary valleys that feed the main rivers of Norfolk, though a few examples which occur lower down the valleys are also conveniently referred to under this name. They are mostly rather small (typically < 5 ha). Their hydrological characteristics are not well known in detail, despite intensive investigations on a few sites (Gilvear *et al.* 1989, 1993), but they are essentially irrigated by groundwater discharge (springs and seepage). In many cases this derives primarily from a Chalk or Pleistocene Crag / Chalk aquifer, but some sites are wholly or partly irrigated with water from superficial deposits and in a few sites this is base-poor and of low pH.

The concept of valleyhead fens in Norfolk encompasses at least three distinctive (though intergrading) types of wetlands:

Spring /seepage fens

These form the most widespread form of valleyhead fen. They are soligenous sites, which typically occupy sloping valley sides kept wet by groundwater discharge, together with surface run-off. Whilst the fens are usually associated with a stream along the valley bottom, this serves mostly to collect and remove water draining from the fen slopes and may have but a rather limited direct effect upon the water budget.

Percolating fens

These sites are most usually located on flattish ground alongside rivers and streams. They are still irrigated by groundwater discharge, usually at the margins, which percolates through the fen to adjoining watercourses, but their water balance is more strongly regulated by the stream or river, particularly because the proximity of the watercourse helps to impede drainage and thus

indirectly helps maintain a high water table in the fen. In some situations it may even directly contribute to the water supply, in at least the lower parts of the fen, by occasional direct inundation in times of flood. This latter situation corresponds to the "transition fens" of Haslam (1960) which, as her name suggests, serve to link valley fens with flood-plain fens. Good examples of percolating fens are rather uncommon in Norfolk. Some of the fens of the Waveney valley (Lopham Fens, Blo' Norton Fen) can be referred to this category, as can Swangey Fen.

Percolating fens in basins

In parts of Norfolk, valleyhead fen sites are formed within small basins (e.g. Great Cressingham Fen) or contain a series of small ground hollows. These may be separate or linked, and sometimes occur intermingled with flushed areas of fen (e.g. East Walton Common). Despite their ostensibly topogenous character, in many cases such basins appear to be dependent upon spring and seepage water for their wetness and they are probably best considered to be a form of percolating fen. It should be noted that in some instances topogenous basins in valleyhead fens have also been produced artificially, by turf extraction (see below).

Distribution of valleyhead fens

Valleyhead fens are widespread throughout much of Norfolk (Fig 1), but they can be loosely grouped into a series of broad, informal geographical categories:

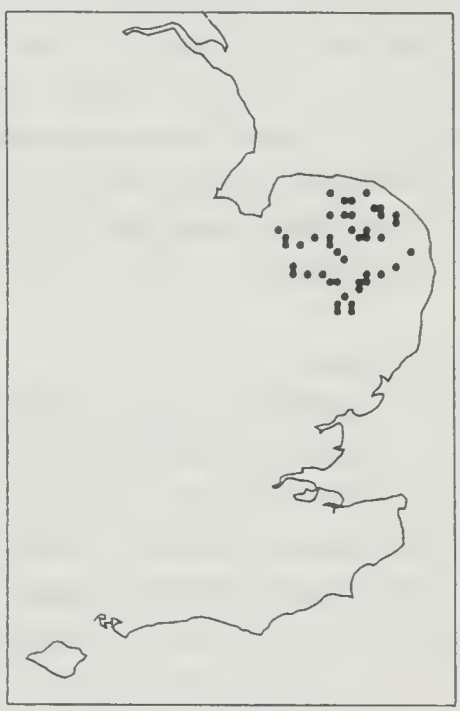

Figure 1. Valleyhead fens in Norfolk

Waveney-Ouse valleys

Redgrave and Lopham Fens form the headwaters of the rivers Waveney and Ouse; others (Hinderclay, Thelnetham and Blo' Norton Fens) occur alongside the R. Ouse (see Bellamy & Rose 1961). All can be regarded as percolating fens, though some examples in side valleys (Weston Fen, Garboldisham Fen) are spring / seepage fens. Most fens lower down these valleys were floodplain fens, and have largely been reclaimed or degraded, though Roydon Fen (Diss) provides an interesting example of a percolating fen lower down the Waveney floodplain.

Breck-Fenland margin

The Breck-Fenland margin is marked by floodplain fen in Fenland proper and in the lower reaches of the valleys draining into The Fens from the east. Most of this wetland has been converted to farmland, but there is still a number of important valleyhead fens embedded within the adjoining upland. Several of these (East Walton, Foulden and Thompson Commons) consist of a series of wet ground hollows, which are widely considered to be the remains of collapsed pingoes. Some of the edges of the floodplain fens were also undoubtedly spring fed and persisted despite reclamation of the wetlands in the main valley expanse (e.g. the Marham Fens that flanked the south margin of the floodplain fens of the R. Nar valley). However such remnants have in most cases eventually succumbed to drainage activities elsewhere in the floodplain, even when direct reclamation has not been attempted. Some valleyhead fens along the Breck-Fenland margin continue southwards into Suffolk, but many of these have been considerably more damaged than their Norfolk counterparts (e.g. Eriswell Poor's Fen) (Haslam, 1960, 1965).

Central Norfolk

This large and diffuse region includes a large number of important valleyhead fens (e.g. Aslacton Parish Land, Badley Moor, Flordon Common, Great Cressingham Fen, Middle Harling Fen, Shotesham Common) several of which are nature reserves (Booton Common, Scarning & Potters Fen, Swangey Fen). Most examples are spring or seepage fens, though both Great Cressingham and Swangey Fens are forms of percolating fen.

thwest Norfolk

don Common provides an excellent example of an acidic valleyhead fen. by, Sugar and Leziate Fens were once important wetlands near the head of Gaywood River, but have been much damaged, both directly (Derby Fen) indirectly (river deepening). Topographically, Dersingham Fen (Bog) is not lleyhead fen, though it probably shares a similar water supply mechanism.

th Norfolk

h Norfolk contains a number of small valleyhead fens, many of which port a form of fen meadow (M22) vegetation. This area also supports a ber of notable fens that are less base-rich than many Norfolk examples eston Bog, Holt Lowes, Bryant's Heath). A series of poor fens also once upied the headwaters of small valleys on the sands and gravels north of wich (e.g. Felthorpe Bog) but many of these have been reclaimed or aded and Buxton Heath is the main remaining representative of these s.

adland

adland is primarily composed of floodplain fen, but true valleyhead fen upies the headwaters and slopes of some of the tributary valleys (Crostwick mmon, East Ruston Common, Smallburgh Fen and, further upstream, threpps Common). Some percolating fens within side valleys (e.g. Decoy r, Acle) and seepage slopes at the head of some of them (e.g. Hemsby mmon) could also be considered examples of valleyhead fens, but they are much part of the Broadland floodplain complex that they are best considered ther with that.

hingland

region once supported several important poor fen valleyhead sites (Belton , Lound Bogs), which have largely been destroyed or degraded.

ny of the valleyhead fens are, and have always been, isolated units (e.g. rning & Potters Fen), but others occur in the headwater valleys of bigger and complexes (e.g. Smallburgh Fen and East Ruston Common occupy the dwaters of tributary streams of the Ant valley in Broadland), where their arent isolation from the floodplain fens lower down the valley is a result rainage of the intervening wetland. Before drainage of the Norfolk river

valleys, it is likely that there would have been a downstream transition between valleyhead fens and floodplain fens (sometimes probably in the sequence spring fen ⇨ percolating fen ⇨ transgression (flooding) fen). No examples of this sequence appear to remain, although some fens do show a lateral (cross-valley) zonation of this type, from groundwater-fed margins to river-flooded centre (e.g. Swangey Fen). However, as used here, the 'valleyhead fen' concept is primarily topographical, not hydrological, so (for example) fens on Broadland flood-plains with spring-fed margins are not considered to be valleyhead fens. Nonetheless, some sites (e.g. Swangey Fen) are topographically intermediate between valleyhead and floodplain fens.

Vegetation of the Valleyhead Fens

The community-type which is most characteristic of the Norfolk valleyhead fens (at least of the base-rich examples) is *Schoenus nigricans-Juncus subnodulosus* mire (M13; *Schoeno-Juncetum*). Norfolk forms the headquarters of this type of vegetation in England (Fig 2), and the only other comparable concentration of sites in Britain is found in Anglesey. In Norfolk, stands of M13 vegetation show a strong relationship to, and dependence on, groundwater discharge, reflecting their requirement for calcareous, nutrient poor water (Boyer & Wheeler 1989) which, in most cases, is derived from a chalk aquifer. They are therefore potentially susceptible to damaging effects of groundwater abstraction, though actual damage that can be unambiguously attributed to water abstraction has only been demonstrated for Redgrave and Lopham Fens (Harding 1993). The M13 community is of much conservational importance (Wheeler 1988) and the international importance of the Norfolk sites with M13 vegetation has been recognised by the proposed designation of most of them as European Special Areas of Conservation ('SAC sites'). However, it should be recognised that this vegetation is often localised to small portions of valleyhead sites, where appropriate environmental conditions prevail.

Juncus subnodulosus-Cirsium palustre fen meadow (M22) vegetation is much more widespread than the *Schoeno-Juncetum* in Norfolk, but is also especially found in valleyhead fens. In Norfolk, it typically occurs in fens, and parts of fens, which are just as calcium-rich as those supporting M13 vegetation, but which are more nutrient-rich and fertile. Along with certain other community-types, such as the *Cirsio-Molinietum* (M24) and *Cladio-Molinietum*, it is

more specific to spring-fed sites in East Anglia than in wetter parts of Britain (where the retention of moist conditions is not so critically dependent upon groundwater sources).

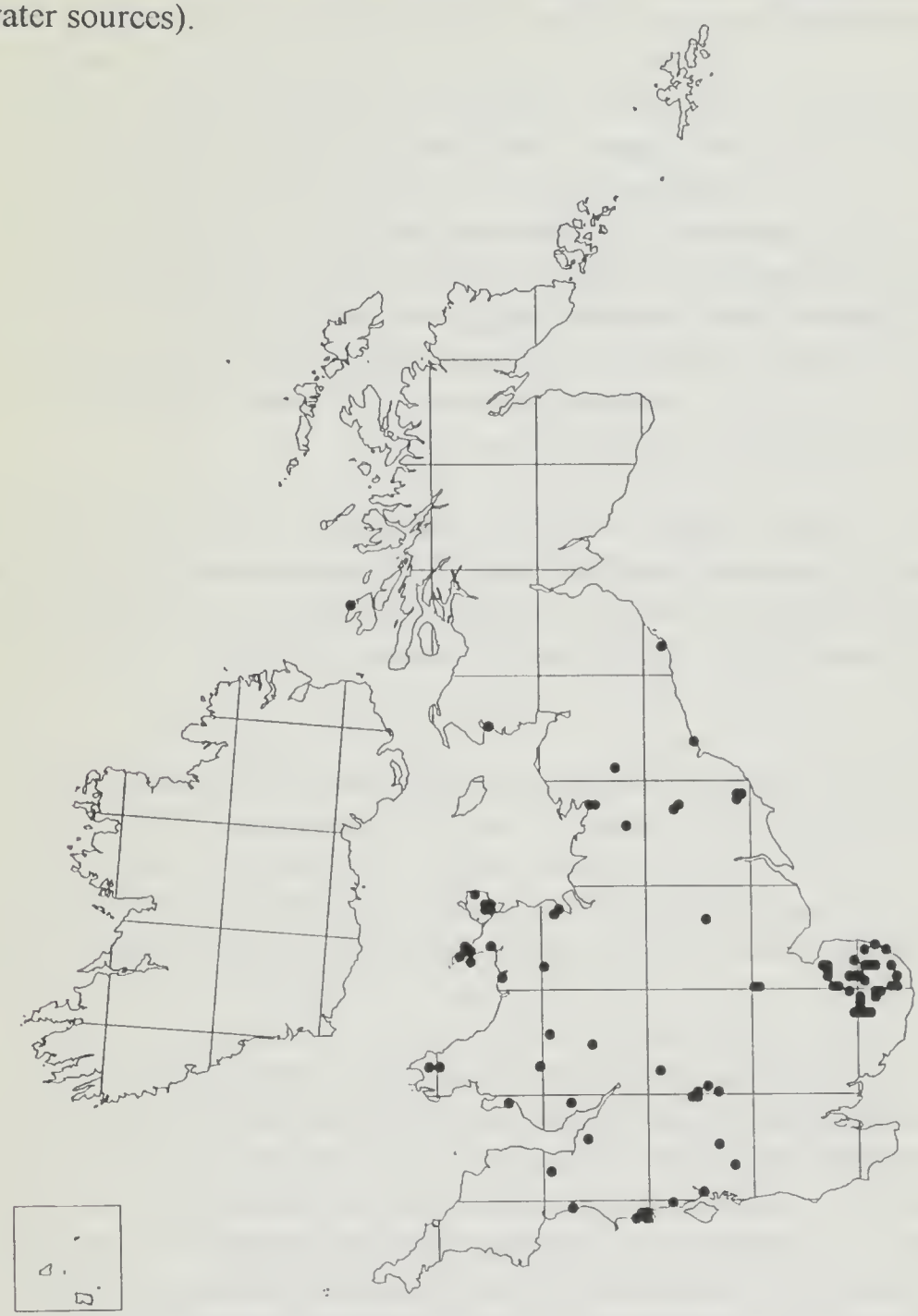

Figure 2. Sites for *Schoenus nigricans – Juncus subnodulosus* mire in Britain

Poor-fen[1] communities are also more specifically confined to valleyhead fens in East Anglia than they are nationally. Some of these (e.g. M21 *Narthecium ossifragum-Sphagnum papillosum* valley mire) are extremely uncommon within Eastern England and the (few) East Anglian examples are of considerable conservational importance. They are mainly associated with discharge of base-poor water from superficial deposits (sands and gravels) or, in the west of Norfolk, from the Lower Greensand. An important feature of several valleyhead sites (e.g. Becston Bog, Buxton Heath, Holt Lowes and Roydon Common) is a zonation in which base-poor seepages on the valley slopes support a poor fen (often *Sphagnum*-rich) vegetation whilst the drainage axis of the valley bottom is much more base-rich. In some cases (e.g. Roydon Common), the axial water tracks support vegetation comparable to *Schoenus nigricans-Narthecium ossifragum* mire (M14).

In East Anglia, *Carex rostrata-Calliergon cuspidatum* mire (M9) is uncommon and represented only as the M9b subcommunity (cf *Acrocladio-Caricetum diandrae* (Wheeler, 1980)). In Norfolk, it is exclusive to certain types of percolating fens, and occurs mainly (but not exclusively) in flooded peat pits.

A wide variety of other herbaceous fen community-types may occur in East Anglian valleyhead fens, but are much less specific to them. In some cases, some of these communities (e.g. *Phragmites australis-Eupatorium cannabinum* fen (S25)) have long occurred in valleyhead fens, partly because, as discussed above, not all parts of such sites are strongly soligenous in character. However, other examples (such as *Phragmites-Urtica* fen (S26) and some other tall herb communities) are not at all characteristic of undisturbed valley fens (Haslam, 1965). They are generally common, adventive community-types of negligible conservational value and their increased prevalence within East Anglian valley fens is because various forms of site deterioration have permitted their establish-ment and increase, as the former constraints upon vegetation composition and distribution have changed or disappeared. Fen woodland is also widespread in many sites, in some cases having replaced former herbaceous vegetation as a result of dereliction.

1. 'Poor fens' are sites irrigated by relatively base-poor water, with pH values typically < 5.5; 'rich fens' are fed with more base-rich water, with pH values typically > 6.0.

Survival of Valleyhead Fen Sites from the Nineteenth Century

Although there are still numerous extant valleyhead fens in Norfolk, only a rather small number have especially high conservation value. This raises an interesting question with respect to the status of these sites. Are the 'high quality' examples that occur today just a small remnant of a habitat that was formerly much more widespread, or was there always just a small number of such sites? Such questions are, of course, difficult to answer, but Wheeler & Shaw (1992) examined this matter with specific reference to *Schoeno-Juncetum* (M13), and allied, sites in Norfolk, on the basis that the distinctive species composition of this vegetation may make it possible to use old species records in *Floras*, and comparable sources, to identify past sites for this type of vegetation and habitat, at least for the nineteenth century.

The interesting conclusion of this study was that, if rich-fen sites alone are considered, relatively few examples of sites from which nineteenth century botanists recorded species characteristic of M9 and M13 communities seem to have disappeared completely (one example appears to be Ellingham & Broome Fen, in the Waveney valley). Moreover, a substantial number of these sites still retain some of the species for which they were formerly noted (or at least did until relatively recently). Such conclusions are of interest, because (a) they indicate that the destruction of base-rich valleyhead fen vegetation over the last 100 years has perhaps been rather less severe than might have been feared; and (b) because they suggest that, even in the nineteenth century, soligenous fen vegetation with M13 type vegetation was probably confined to a rather small number of well-known sites and was not dramatically more widespread than it has been in more recent times.

As with most sweeping generalisations, various caveats need to be observed. The first is that the conclusion refers specifically to base-rich valleyhead fens that once supported high quality *Schoeno-Junceta* and related vegetation (or at least their nineteenth century analogues): there has been a more precipitous loss of base-poor valleyhead fens and a smaller proportion of nineteenth century poor fen sites survive than is the case with rich fens. For example, the once-important poor fens of Lothingland, which provided Paget & Paget (1834) with numerous species records, have almost entirely disappeared or have been degraded, just as have many of the poor fens (and wet heath) in the acid sands and gravels to the north and northwest of Norwich, which gave Trimmer (1866,

1885) and Nicholson (1914) a series of localities for wet heath and fen species from places such as Felthorpe, Horsford, Hainford and Newton St Faiths. A second caveat is that there may have been considerably more 'good' East Anglian valleyhead fen sites in the nineteenth century than those of which we are currently aware, but they were not well known to contemporary botanists. There is certainly reason to suppose that not all the 'good' sites were well known. For example, there is a marked lack of early records from the important *Schoeno-Juncetum* site of Badley Moor, even though Clarke (1918) seems to have visited it.

Nonetheless, whilst there may well have been some such unknown sites, the nineteenth century botanists were undoubtedly well, and perhaps selectively, familiar with many of the species-rich groundwater-fed fens that exist today. Inspection of *Floras* frequently indicates a greater proportion of records from valleyhead sites than from other wetland areas (with the important exception of Broadland). This may be because the soligenous sites were of particular botanical interest (i.e. had more and rarer species) - a possibility which itself suggests that such vegetation was even then not very widespread. By comparison, many of the badly-drained valley bottom, floodplain wetlands may have had a tendency (as they do now) to be comparatively species-poor, to support a less notable complement of species and to offer less attraction to the attentions of botanists.

Drainage for agriculture

It can also be suggested that some valleyhead sites survived the drainage initiatives of the early nineteenth century rather better than did some of their floodplain counterparts. From the perspective of present-day concerns about low water tables, it is easy to forget that major drainage of many East Anglian fens was associated with the Inclosure movement at the end of the eighteenth century (and in some cases well before then). If the maps of Faden (1797) can be taken as a reliable guide, the bottoms of many of the river valleys in Norfolk and Suffolk were badly-drained areas of marsh and rough pasture towards the end of the eighteenth century, but by the mid-nineteenth century many of these once-waterlogged floodplains had been drained and improved and may have scarcely merited much botanical investigation. Some valleyhead sites undoubtedly also succumbed to the initiatives of the Commissioners for Drainage, but it seems most probable that the floodplain

wetlands were often the priority targets for drainage and reclamation, because they were extensive, relatively fertile and comparatively easy to drain (for summer-dry conditions, at least). That contemporary agriculturalists appreciated the potential value of the floodplain wetlands is nicely illustrated by a comment of Young (1804), a noted 'improver', referring to the vicinity of Sculthorpe Mill (and Fen): "Of all the nuisances that a country can be plagued with, certainly water mills are very high in the black catalogue; for the sake of this beggarly mill [Sculthorpe Mill], which apparently cannot be worth more than from 20 *l.* to 30 *l.* a year, here is a noble tract, from a furlong to a mile wide, of what ought to be rich meadow, poisoned with water and producing rushes, flags, sedge and all sorts of aquatic rubbish."

By contrast, the opposite was true of many of the valleyhead sites. They were frequently rather small, often not 'good' land and, where there were strong springs, not at all easy to drain. Burrell and Clarke (1913) clearly appreciated the difference in agricultural potential between these two wetland types: "Artificial drainage and grazing improve these swamps [ie. marshes along valley bottoms] into alluvial pasture; but where spring heads occur, and especially where both soil and water are deficient in food salts, the natural balance of species is retained." Thus there was a tendency for spring fed areas not to be reclaimed, even though there were doubtless some farmers who were prepared to follow Young's (1804) commendations and instructions to attempt this quite difficult task.

The Importance of Poor's Land

A large number of the 'best' extant valleyhead fens are in land parcels that were set apart at Inclosure as Poor's Allotments, or have some other form of 'Common Land' status. This observation is by no means novel - Haslam (1960) recognised that most of the 'wet fens' she examined on the Breck - Fen margin were Poor's Allotments. It is therefore of some interest to try to establish the basis of this relationship.

One possible explanation of the importance of Poor's Allotments for fen plant species is that they have been 'protected' from more intensive exploitation by their status. However, whilst this suggestion may have some validity, it is by no means axiomatic. In some cases, even at Inclosure, the allotment of Poor's Land may have led to some improvement or change in use. Again Burrell and

Clarke (1914) provide useful insights: "On Horsford Heath, St Faith's Common and Newton Common, natural regeneration of pine is taking place. Horsford Heath was formerly manorial waste subject to common rights; the trees were suppressed as a matter of policy by the common-right holders and villagers now living remember it as open heath. Since its allotment to the poor at enclosure, the trustees have protected the seedling trees, and it is now open canopy forest, the small annual produce being divided amongst the poor." In other situations too, 'Poor's Land' was sometimes rented or sold for use for more productive agriculture and in some instances this has led to improved drainage and even cultivation of the fen sites. Moreover, even when Poor's Fens themselves have not been directly improved, they have not been immune to the effects of drainage schemes in adjoining land parcels, as is well illustrated by the indirect dehydration of Caldecote Fen (Oxborough Fuel Allotment) in a tributary valley of the R. Wissey.

An alternative explanation of the relationship between Poor's Land and extant botanically-rich valleyhead fens rests upon the intrinsic character of many of the allotments given to benefit the land-dispossessed poor. These often included some of worst land in the parish, from the point of view of agriculture. For example the Charities Commissioners Report for Hevingham parish (Norfolk) observed in 1838 that "This allotment [= Buxton Heath] consists of very bad land; it is not let but given up to the poor for the purposes of cutting fuel thereon." Likewise the Tithe File suggests that "The western part is heathy interspersed with belts of Scotch fir and it is a poor black gravel fit for nothing" - except, presumably, the Poor. The Commissioners also report for Helhoughton Fuel Allotment: "Upon the Helhoughton Inclosure an allotment of about 20 acres was set out for the poor. This is very bad, wet land, not worth cutting for fuel and nearly unproductive. A poor man is allowed to turn his cows upon it". In many parishes much, or all, of the land allocated to the Poor was that which was regarded as being particularly difficult to improve for example, land which was particularly impoverished and which had strong, difficult-to-drain springs: conditions which had little agricultural merit, but which were ideal for species-rich soligenous fen vegetation. Seen from this perspective, 'good' valleyhead fen sites have not so much survived because they were Poor's Land but they were Poor's Land because they were 'good' valley-head fen sites!

The *Reports of the Charities Commissioners* indicate clearly that many of the Poor's Fens were subject to some degree of vegetation management, usually some form of mowing (for reed, 'sedge' or litter) or low-intensity grazing, practices which continued into the twentieth century but which have often since been abandoned, until the relatively recent resurgence of interest in these sites by conservationists. There is no doubt that many of the less common species of the valleyhead fens (e.g. *Epipactis palustris* and *Parnassia palustris*) are associated with low-growing vegetation and are liable to disappear with the development of rank, herbaceous vegetation or the establishment of fen woodland.

Turf Cutting in the Valleyhead Fens

The peat resource of some valleyhead fens was probably important as a source of domestic fuel long before Fuel Allotments were allocated during the Parliamentary Inclosures. However, much of the (scanty) information available about turf cutting in these sites derives from the Poor's Fens, as rates of extraction were sometimes recorded by the Overseers and Trustees of the Poor's Charities and, in rather fewer instances, this information has survived. For present purposes, the *Reports of the Charities Commissioners* made during the 1830s provide a useful, if brief and incomplete, synopsis of turf extraction in Poor's Fens.

Rates of extraction

Perhaps the most remarkable feature of turf extraction is the high rate at which it appears to have been carried out. Permissible maxima of 4000-5000 turves per household per year are commonplace, and in a few sites there were consents for eligible cottagers to remove up to 8000 turves per year. Whilst right-holders may not always have cut their full entitlement to turf, extraction on this sort of scale undoubtedly had a major impact on the peat resource of the sites and in some cases led to its virtual depletion. Right-holders of East Ruston parish were particularly fortunate in being endowed with a supply of turf within some 11 allotments. Bird (1909) indicates that, in these Allotments, turf extraction was carefully regulated, in terms of date of extraction and number of turves cut. Yet even in this well-supplied and well-ordered parish there seem to have been concerns about the sustainability of the resource. In 1845 the sale of turf outside of the Poor of the parish was prohibited; in 1853 the maximum number of turves per household was reduced from 5000 to 3500; both dictates suggest

a concern over the rate at which the resource was being exhausted.

In other parishes, there was apparently rather less regulation. The Charity Commissioners for Norfolk several times report a free-for-all in the use of the Poor's Land and consequent exhaustion of turf. For example, at Wendling Fuel Allotment "Turf has been cut without restriction and is now almost exhausted". At present Wendling Poor's Fen (Holly Farm Meadows SSSI) has an almost skeletal substratum in places, with only some 30cm of peat even in the deeper depressions (Wheeler & Shaw, 1987), to the extent that it is difficult to imagine a much deeper peat resource.

Impact on the peat resource

It is difficult even to guess the total amount of peat that has been stripped from valley fen sites. This is because the extent of pre-Inclosure turf removal is generally unknown, and because even when permissible rates of post-Inclosure extraction are specified it is not known how closely they were followed, nor how many cottagers cut turf, nor even the size of the turves (which probably varied between parishes). However, if it is assumed that the typical size of turves were comparable with those cut using a turf-becket of, say, about 4" x 4" x 12" depth[2], then extraction of 1000 turves would equate to removal of a volume of some 3.0m^3 of peat. Even at the modest rate of 3000 turves extracted per year, if 20 right-holders were cutting, it would take only some 50 years for 1m depth of peat to be stripped from 1ha of fen. Thus perhaps it is not surprising that in most East Anglian valleyhead fens the peat depth is consistently shallow (<50cm (Wheeler & Shaw 1987)). And even though there are still some relatively deep (> 2m) peat reserves in a few sites (mainly

2. Beckets of some 18" x 4" x 4" were used in the latter-day "commercial" peat cutting of The Fenland peats around Mildenhall (Trist, 1971) and Wicken (Day, 1985), though there was considerable variation in dimensions from place-to-pace. Skertchly (1877) suggests average dimensions of 9½," x 6¼" x 4". Little information has been located relevant to the Poor's Fens, though the Inclosure documents for Tuddenham suggest extraction of 4" x 4" turves. It is likely that the size of turves removed may have varied between parishes (Skertchly, 1877), and perhaps within them for, as Day (1985) comments "Digging for themselves on the common turbaries men were apt to use larger than the commercial beckets to dig out all that they could while they were about it"! The size of becket used in this present calculation is therefore fairly modest. Note also that calculation of the volume extracted is also hampered by the possibility that the number of turves making up 'one thousand' may have depended upon their dimensions (Day, 1985).

in the Waveney-Ouse valley), these may also have once been much deeper. It would be intriguing to know the original depth of peat in some of these sites, especially in those examples where the valleyhead topography could once have contained a substantial peat infill. Is it possible that present-day valleyhead sites, such as Buxton Heath or Scarning Fen, were once filled flat-across with peat ?

Turf cutting and vegetation

Turf cutting has undoubtedly had an impact upon the vegetation of the valleyhead fens, though its effect has varied from site to site. In some of the percolating fens with deeper peats, peat was usually dug as a series of pits, an--alogous to the turf-ponds of Broadland (Wheeler 1983). These have often become reflooded to form water-filled hollows (which have since sometimes terrestrialised by the formation of a semi-floating hover to form swamp and wet fen) and where this was the case, it led to a marked increase in wetness of the fen surface. This outcome was not universally welcomed and it possible that some of the Norfolk cottagers may have echoed the view of Vancouver (1794) with regard to Burwell Fen in Cambridgeshire, when he observed that a considerable part of this site "has been greatly injured by digging turf ... constantly inundated ... a most deplorable situation ... water encourages the growth of reed and sedge, ... cut by the poor..". But whatever the agricultural viewpoint, there can be little doubt that turf cutting helped to produce pools and swamps in sites from which, in some cases, these had long been absent and provided a basis for the subsequent development of uncommon vegetation types (such as *Calliergon - Carex rostrata* mire) with a range of unusual species, including in some cases *Liparis loeselii.* Such water-filled pits were probably quite widespread, but are particularly well known from East Ruston Common and some of the Waveney-Ouse fens, partly through the graphic description of Clarke (1918): "Many of them, notably Blo' Norton, and parts of East Ruston and Burgh St Margaret, consist of a mass of vegetation floating on an unknown depth of water and mud. The floating carpet yields at every step; the surface for yards round becomes tremulous....Unpleasant, though not dangerous, is the effect of new and old peat workings, which occur over most of the fens. Walking carefully in nine inches of water, the depth of which is hidden by the vegetation, a sudden drop of two feet or more into an older peat working is apt to interrupt botanical investigations for a time. Further troubles are caused by the sharp edges of the sedge and the saw-like teeth of *Cladium* ,

the stumps of reed cut below the water, the slipperiness of the putrid mud, and the fall from the narrow ridges that interseet peat workings. Happily, however, these drawbaeks preserve *Liparis* and other Norfolk rarities from the ravages of the eolleetor."

ın the different topographieal eontext of sloping spring and seepage fens, peat extraetion has less often produced deep pits full of standing water, but has more typieally generated a series of shallow trenehes and hollows, or even a uniformly-stripped surfaee. On abandonment, such workings have usually created a wet or swampy environment within the fen, rather than a turf pond over whieh hover eould develop. In some sites abandoned workings have helped foeus and funnel the diseharge of spring water aeross the peat surfaee, though in others, the moving water has itself helped to erode and eoalesce some of the irregularities produced by peat-winning.

One possibly important, but little considered, further impact of peat removal in some of the valleyhead fens, is that removal of peat may have helped to expose the strong springs and seepages upon which eommunities sueh as *Schoeno-Juncetum* nowadays depend (Wheeler & Shaw 1987). Is it possible that, particularly in the soligenous fens, the present present-day *Schoeno-Junceta* did not just survive peat extraetion but are, at least in part, a eonsequenee of it?

Perceptions of Change and Causes of Change

Whereas a quite large proportion of the valleyhead fen sites known to nineteenth century botanists have survived in some state, others have undoubtedly been badly damaged or destroyed. Moreover, there is a widespread perception that floristie quality has deelined in many extant examples, though this is often diffieult to assess, not least because of the absenee of eomprehensive past (and sometimes modern) speeies records for individual sites. The eauses of sueh presumed floristic loss may be even harder to identify.

Wheeler & Shaw (1992) eollated information from a wide range of published and unpublished sourees relating to speeies loss, and its eauses, in valleyhead fens in East Anglia. A summary of the results for this, for Norfolk, is given in Table 1. It must be emphasised that not all of the information presented here is based on hard evidence - sometimes evidenee for floristie deterioration, and particularly the causes of this, is based just upon the opinions and beliefs of

individual observers which, in some cases, may be ill-informed. Moreover, it is suspected that in some instances individuals may have suggested that sites are 'drying out' simply because the surface was relatively dry at the time of their visit. It should also be noted that the 21 sites for which there is no evidence for loss of flora are not necessarily species-rich sites; some have probably always been rather species poor.

Table 1. Recorded perceptions of change in 73 valleyhead fens in Norfolk. Numbers represent the number of sites in each category and are based upon the views expressed in published and unpublished sources. Based on information collated by Wheeler and Shaw (1992)

	Loss of flora	Drying	Dereliction
None, or not known	21	20	6
Slight	15	21	19
Moderate	10	11	31
High	12	10	10
Severe	12	6	1

Drainage and Dehydration of valleyhead fens

There is no doubt that drainage has been an important reason for the deterioration, or destruction, of some valleyhead fens. River over-deepening, mainly during the last three decades, is likewise thought to have been detrimental to a quite large number of sites, including the Waveney-Ouse fens, the fens of the Gaywood River valley and possibly Swangey Fen.

Currently, groundwater abstraction is perceived to be an important threat to the dehydration of some valleyhead sites, though the magnitude of this problem is not really known. At present, there is only clear evidence for a strongly-damaging effect of groundwater abstraction upon two valleyhead sites (East Ruston Common (Binnie & Partners 1995) and Redgrave & Lopham Fens (Fojt & Harding 1995)). Although it is possible that this may be just a consequence of lack of appropriate evidence for other sites, equally it must be recognised that observed dryness of fen surfaces is not necessarily a product of ground-

water abstraction. Even in the Redgrave & Lopham Fens, reports of dehydration are of long standing and predate the water abstraction initiatives of the 1960s. For example, Geldart (1901) was prompted to comment that "Marshes near the source of the Waveney are the best known habitat of *Malaxis paludosa* and still yield *Liparis loeselii* - these marshes have become distinctly drier and the number of individuals of the rarer plants, although not perhaps the number of species to be found in them, has diminished within the writer's experience." Similarly, in an unpublished report, A.G. Tansley and A.S. Watt commented that in 1949 "Little Fen and Redgrave Fens are good mowing fens, but the surface was very dry (possibly due to the weather)".

Droughts are an occasional natural feature of many wetland sites and even before current concerns about climatic change and groundwater abstraction, dry episodes in wet fen sites were well known. Drought conditions in East Anglia in the early 1920s (e.g. Clarke 1922) had a very considerable effect upon the water supply to some valleyhead fen sites. For a time even the turf ponds in the normally-wet East Ruston Common were bereft both of water and *Utricularia* species (Gurney 1922; and Diaries 1922; 1923) though both water and, more slowly, *Utricularia* eventually returned.

Another complication is that perceptions of drying may sometimes stem from ongoing peat accumulation rather than water loss. This can be particularly evident at sites rich in abandoned peat pits where ongoing terrestrialisation can quite rapidly stabilise swamp or hover to form ostensibly 'dry' and firm fen surfaces. A good example of this seems to be provided by a comment made by G.H. Rocke (*in litt.* to F. Rose 1958), with reference to Shallam Dyke, Thurne (this is a now-drained Broadland side valley fen which has many of the topographical attributes of a valleyhead fen): "*Carex limosa* seems to have forsaken Thurne ... I cannot see that they have drained the bogs; but the swamps seem of their own accord to have become drier. " Shallam Dyke was full of old turf ponds. From such a viewpoint it is possible to speculate that perhaps Geldart's (1901) comments on the dry state of the Waveney-head fens may have stemmed from a comparable cause. Such considerations are of great importance because they point to the likelihood that, even without an actual reduction in water tables, a strategy of rotational turf removal may be needed to maintain the perceived conservation interest of some valleyhead fens.

Other causes of vegetation change

Water is only one of the determinative influences on the composition of fen vegetation. The other main casual factors are pH, nutrient status, management activity and (in some sites) successional state (Wheeler & Shaw 1995). Some of these processes are difficult to disentangle from one another: for example, both nutrient enrichment and lack of management can promote the development of a rank, species-poor vegetation (Wheeler & Shaw 1989). Likewise, low water levels can, in some circumstances, lead to nutrient release (by mineralisation) and pH reduction; they can also promote scrub invasion. Accordingly, without past environmental measurements or detailed floristic data (and these do not exist for most Norfolk fens) it is often difficult to interpret the likely causes for apparent vegetation changes. In consequence it is often not possible to assess rigorously, for example, the extent to which fens in Norfolk have become enriched with nutrients, though in some cases this can be guessed.

Likewise, there are few detailed data available about changing management practices in the valleyhead fens during the twentieth century, but at least here it is possible to observe the obvious - that in many sites, former management has been abandoned. One clear example of the effect of dereliction upon valleyhead fen vegetation is provided by Rockland All Saints Fen, from which F. Rose recorded species of a *Schoeno-Juncetum* community in 1960 but which was dense alder carr by 1973 (Table 2). Rose has had a long familiarity with the Norfolk fens and recently provided an informed perspective on the perception and causes of recent vegetation change within them:

"On my visits to Norfolk in 1991, however, when I revisited many of the sites, I was relieved to find that the main problem in many fens involve coarse sedge, scrub and woodland growth, rather than a catastrophic water table drop, and in these cases appropriate management could relieve the situation - in some cases the situation is already improving. Scarning Fen, for example, is now quite good as was when I first saw it in 1956... The water table also seems to be fairly good so far at Buxton Heath[3], Holt Lowes and Roydon Common, all spring-fed mires." (F. Rose, *in litt* 1992).

3. some other observers report evidence of dehydration at Buxton Heath)

Table 2. Stand composition of alder carr at Rockland All Saints Fen in 1975

This stand provides an example of alder carr recorded from a location which has supported *Schoeno-Juncetum* (M13) in 1960. Figures represent the Domin cover-abundance of each species

Rich Fen Vegetation Survey

Rockland All Saints Fen
Stand Composition

FenBASE 3.2 1973

Stand: 1 Alder carr

Alnus glutinosa (c)	6	*Mentha aquatica*	4
Rhamnus catharticus	3	*Myosotis laxa caespitosa*	3
Salix cinerea	3	*Poa trivialis*	3
		Ranunculus repens	3
Rubus fruticosus agg.	3	*Urtica dioica*	3
		Valeriana dioica	4
Solanum dulcamara (g)	4	*Valeriana officinalis*	3
Ajuga reptans	3	*Carex acutiformis*	3
Berula erecta	3		
Caltha palustris	3	*Dryopteris dilatata*	3
Cardamine pratensis	3		
Cirsium palustre	3		
Eupatorium cannabinum	4	*Brachythecium rutabulum*	3
Filipendula ulmaria	3	*Eurhynchium praelongum*	3
Fraxinus excelsior (c)	3	*Mnium hornum*	3
Galium aparine	3	*Plagiomnium undulatum*	3
Iris pseudacorus	3		
Lythrum salicaria	3		

Conclusions

Notwithstanding the obvious limitations of the data (Table 1), there is strong reason to suppose that a considerable number of the Norfolk valleyhead sites have shown, or are thought to have shown, some floristic deterioration, as determined by the loss of the less common fen species, and particularly by the loss of those that are typically associated with consistently wet conditions (Wheeler & Shaw 1992).

Many of the sites which have shown a deteriorating flora show some evidence of dehydration. In some cases, this may be related to groundwater abstraction; in others to deepening of adjoining drains and watercourses. However, even more valleyhead fens show evidence of dereliction, in some cases so deep-seated that former herbaceous communities have been almost entirely replaced by fen woodland (Table 2). Thus it can be assumed neither that all valleyhead fens in East Anglia are 'drying out', nor that dehydration is the only cause of floristic change (see also Wheeler & Shaw 1995b). However, relatively high water tables are undoubtedly associated with high vegetation quality in the valleyhead fens and it is notable that the fens which F. Rose (quoted above) thought were not suffering from water loss are all examples which have shown relatively little floristic deterioration.

It is most important to try to establish causes of change - and ongoing threats - at individual sites, not least because there seems little point in attempting to rectify the effects of water loss if sites are allowed to deteriorate for quite separate reasons, such as lack of management. The potential for recreation of *Schoeno-Juncetum* vegetation by re-instatement of management in badly derelict sites is not known. It is, however, important to recognise that its distribution is controlled by soil and water conditions as well as by management, and that management initiatives are unlikely to restore, or extend, the community into inappropriate edaphic conditions, though they may well result in the re-instatement of commoner, less demanding, communities such as fen meadow (M22).

The survival of *Schoeno-Junceta* (and other) community-types in their nineteenth century sites up to the present day suggests that they are quite resilient to, and may even benefit from, a range of activities, including vegetation management and peat removal. However, the fact that there is no

evidence for a very much wider distribution of such vegetation in the nineteenth century suggests that it has rather specialised habitat requirements, which are realised only in a rather small number of sites. Such limited assets require particularly rigorous and sensitive protection.

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Miscellaneous observations

"I wondered if you could identify these tiny creatures for me? We have some cork mats in our oak dresser and there are loads of these tiny little 'beetles' on them. We found sand hills under the mats so they must have eaten or tunnelled through them. I can live with springtails in the conservatory but..." So began a letter from a lady in Brundall to Ken. Durrant. The creatures, smaller than pin pricks, had been stuck under sellotape onto the letter. They proved to be free-living bark-lice (Psocoptera) but even Ken Durrant could not identify them beyond the genus level under the sellotape. They were living on microfungi in the cork place mats. The lady regularly cleaned the underneath of the mats with a damp cloth to create, unwittingly, the ideal conditions for the microfungi to thrive. The bark-lice then enjoyed the food and habitat provided.

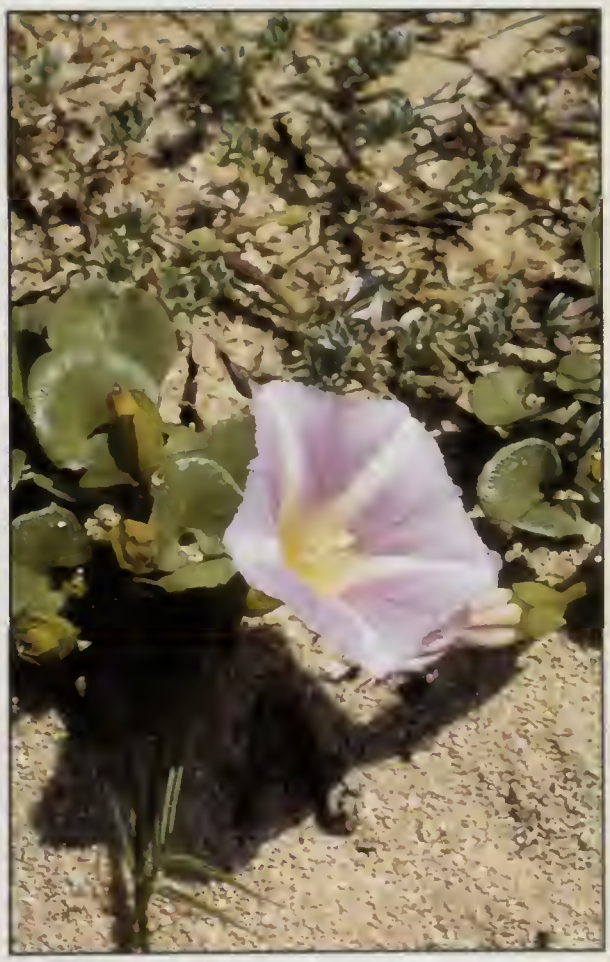
The advice was given to stop using the damp cloth but, alas, the place mats had been discarded into the dust bin.

WILDLIFE 2000

One of the aims of the **Wildlife 2000 Project** is to record a miscellany of observations of the natural history of Norfolk. In these six pages of the *Transactions* a selection of photographs by members of the Society's Photographic Group illustrate some of the diversity in the flora and fauna of the county.

Ragwort, *Senecio jacobaea*
(Reg. Jones)

Sea bindweed, *Calystegia soldanella*
(Reg. Jones)



The bluebell wood (Tony Howes)

Poppy delight (Tony Howes)

Sea milkwort, *Glaux maritima* (Reg. Jones)

Yellow horned poppy, *Glaucum flavum* (Reg. Jones)

Wasps' nest (Bob Robinson)

Coastal erosion at West Runton (Bob Robinson)

WILDLIFE 2000

THE AQUATIC MACROINVERTEBRATE FAUNA OF THE LITTORAL ZONE OF THE NORFOLK BROADS 1977-1995

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Introduction

The littoral zone is the shallow region around the edge of a lake where suffieient light reaches the bottom to enable submerged macrophytes to take root and grow. Because the broads are generally very shallow - the vast majority averaging less than 3m deep - under natural circumstanees and with reasonably clear water, most of the lake ought to be open to invasion by a succession of first submerged and floating plants and then emergents like club-rush and reed. On the landward side, a similar process leads to the formation of swamp carr and ultimately to ash/oak woodland. Formerly, most of the broads are known to have featured natural hydroseres with rich littoral communities, made up of wide fringes of emergent and floating-leaved vegetation, which extended out into the open water to form floating rafts that are clearly visible from early aerial photographs; these show hundreds of small 'atolls' that give the surface a 'reef-like' appearance (Jackson 1978). Black-headed gulls, *Larus ridibundus*, formed huge nesting colonies amongst these islands, partieularly at more isolated broads, such as Hoveton Great Broad and Alderfen Broad (Riviere and Ellis 1965). The complex spatial heterogeneity of these littoral habitats would also have been home to a diverse aquatic macroinvertebrate community.

There are no sueh reef-like habitats remaining in any of the broads. In fact, littoral habitats in general began to disappear at the turn of the century, although the losses only became noticeable on the ground in the mid-fifties (Boorman, Fuller and Boar 1979). Many of the rarest species vanished almost overnight, to be replaced by rank submerged plants or more often by murky water devoid of any vegetation barring a few water lilies. By the mid-seventies the impoverishment was practieally universal, although the Thurne and Trinity systems were less affeeted.

The decline of submerged macrophytes has been widely attributed to escalating rates of nutrient enrichment and sedimentation (George 1992) although, as I hope to demonstrate, a number of crucial biotic interactions may have been overlooked. In addition to chemical effects, the emergent plants succumbed also from excessive boat wash from motor cruisers and intensive grazing pressure from feral coypu (*Myocastor coypus*) and naturalised geese (Ellis 1963 and Smith 1995).

The decline in the Broadland plant communities has been fairly well-documented through a combination of searches of the literature, trawls through herbarium material and palaeolimnological work on sediment cores (Jackson 1978, Moss 1977 and 1979). Because there is often a strong association between plant architecture and the composition of macroinvertebrate communities (Jackson 1997) it is more than likely that the decline in the plants during the fifties and sixties was matched by corresponding changes in the macroinvertebrate communities (Palmer 1981). The precise nature of these changes however have been difficult to establish because, despite the very valuable work of redoubtable naturalists, such as Frank Balfour-Browne, Robert Gurney and Ted Ellis, who all made detailed studies of specific groups or areas, these proved to be of limited use for the comparative analysis of the system in quantitative terms.

Thus, in 1977 the Nature Conservancy Council (now English Nature) established permanent transects for the surveillance of submerged macrophytes and fixed sampling stations for littoral macroinvertebrates in twenty broads. Samples of macroinvertebrates were thus taken in unison with the aquatic macrophyte transects in 1977 (see Jackson 1983). Macrophyte surveys have been conducted by the Broads Authority on an annual basis ever since (Kennison 1983-1993, Kennison and Prigmore 1994 and Dunsford 1996), but the macroinvertebrate programme was 'mothballed' due to a lack of funds. It was not until the mid-nineties, having recognised the potential significance of the 1977 benchmark, that funds were made available by the Broads Authority to identify the remaining 1977 samples, but crucially also, to enable the survey to be repeated in 1995. This paper summarises the results of the work and offers a tentative interpretation of the findings.

Method

The survey broads were selected from the Bure, the Ant, the Thurne and the Yare valleys, to reflect as wide a range of conditions as possible. The broads of the Waveney catchment were not sampled. A list of the sites chosen is given in Table 1 which shows the acreage (after George 1992), grid reference, number of sampling stations (N) and dates on which each broad was surveyed in 1977 and 1995.

Broad	Area (ha)	Grid Ref. (TG)	N	1977 Survey Date	1995 Survey Date
Alderfen	5.0	35 19	12	30/08	18/08
Belaugh	2.0	29 17	12	08/08	11/07
Blackfleet	1.5	44 21	5	14/09	19/09
Burntfen	4.5	33 18	10	16/08	18/09
Crome's	4.5	37 19	15	23/08	15/08 + 24/08
Decoy	10.0	32 16	11	26/07	17/09
Filby	42.0	45 13	9	21/09	23/08
Hoveton Great	25.0	31 16	15	21/07 + 04/08	25/08
Hoveton Little	20.0	33 17	12	02/08	14/09
Hudson's Bay	4.5	31 16	8	29/07	19/09
Lily	5.0	45 14	9	27/09	23/08
Malthouse	11.0	35 14	7	08/09	17/08
Martham South	8.5	45 20	9	05/09	18/08
Ormesby	56.5	46 15	17	02/09 + 12/09	21/08 + 22/08
Ormesby Little	50.0	46 14	12	23/09	23/08
Ranworth	29.0	35 15	14	08/09	17/08
Rockland	21.0	33 05	19	28/07	14/08
Rollesby	35.0	46 14	13	05/10	23/08 + 24/08
Surlingham	14.5	32 07	11	25/08	22/08
Upton Big	5.5	38 13	7	07/10	16/08

Table 1. The 20 survey broads, their acreage, location, number of sampling stations (N) and sampling dates.

Sampling was carried out between July and October and repeated in 1995 in the same season as the 1977 survey. The position of the sampling stations was determined by the placement of the macrophyte transects and thus most of the stations fell in floating-leaved or emergent plants around the margin of the broad. Samples were also taken amongst the roots of overhanging tall-herb vegetation and carr. The sediment was not sampled. Five principal habitat types were chosen; the roots of carr, emergent vegetation, floating-leaved plants (lilies), submerged vegetation and open water, but because there were so few of the latter two groups these stations were excluded from the study. Fig. 1 shows the division of the principal habitats between the remaining sampling stations. Note that a few stations had changed status due to management in the intervening period.

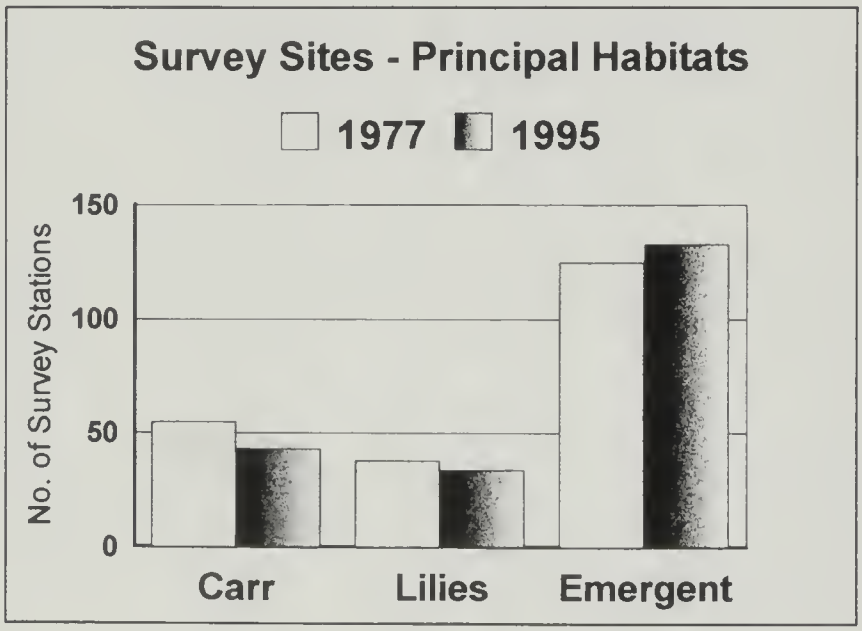

Figure 1. The distribution of sampling stations among the principal habitat types.

All the sampling was carried out from a small rowing boat. At each sampling station all the littoral vegetation in the immediate vicinity was sampled with a standard ISO hand-net (with a 1mm mesh size and a 1.15m handle) using a combination of long sweeping movements coupled with vigorous netting of the vegetation (Biggs *et al* 1998 and Jackson 1997). Care was taken at all times not to stir up the sediments.

In 1977, no set time-limit was imposed, but generally speaking at least five minutes was spent searching and fifteen minutes sorting at each sampling location. More time was spent at sites that looked promising and a whole day was spent sampling broads like Hudson's Bay and Rockland Broad, where there were extensive lily beds. At each station, specimens of all the taxa that were caught were taken away and preserved.

A more precise procedure was adopted in 1995, using the same technique, but for a period of exactly one-minute and this time retaining the whole catch. This change enabled comparison with the presence or absence data of the 1977 survey whilst allowing for more detailed statistical analysis (requiring abundance estimates) of the 1995 data. The sampling was carried out by the author.

The material was sorted in a 40 x 30mm white plastic tray from debris and loose vegetation on site. The debris was scoured for organisms that clung to the vegetation, such as leeches and damselfly larvae. The catch was placed in containers, strained of excess water and then preserved in 70% Industrial Methylated Spirit. In the 1977 survey the smaller bivalves, cladocerans, ostracods and water mites were ignored, but all these groups were collected and identified in 1995 (these results are not included in this paper). Triclads and oligochaetes were ignored because after prolonged immersion in alcohol they are impossible to identify reliably.

Identifications were made to species level where possible and in the 1995 survey absolute numbers were recorded. With the available keys, it was impossible to make reliable identifications of some groups, particularly to separate many of the juveniles and earlier instars. These were either grouped together and considered as one taxa, for example the Coenagrionidae, or they were simply counted and discarded, as with the corixid nymphs. Identification of chironomid larvae proved to be such a painstaking process that it was decided reluctantly to store this material for future study. Most identifications were double-checked and all rarities were confirmed by the relevant authorities. The records were entered on the Joint Nature Conservation Committee (JNCC) RECORDER system.

Results

The results considered here include only the directly comparable data between the two surveys (i.e. presence or absence data only) - the additional groups covered in the 1995 survey are not considered.

A total of 119 species were recorded; 75 in 1977 and 111 in 1995 amounting to an additional 36 species in 1995. The number of records (i.e. a record of one species at one station) logged was 1,464 in 1977 and 2,465 in 1995 - an increase of about 1,000 records or approx. 68%.

Figure 2 shows the difference between the number of species per sample in 1977 and 1995. The median (arrowed) for 1977 was five species per sample and for 1995 was ten species per sample.

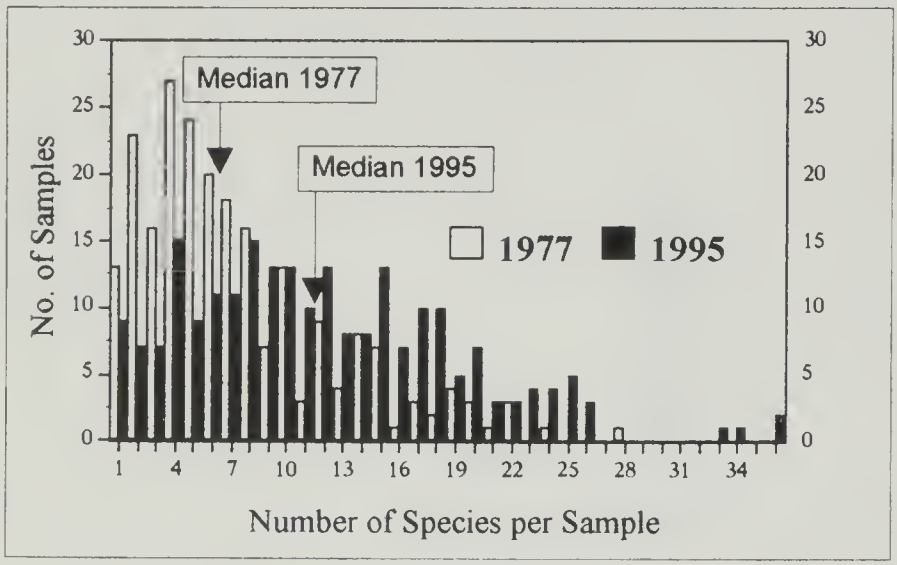

Figure 2. The frequency of number of species per sample in each of the surveys.

There were significantly more species per sample in 1995 than in 1977 (Two-sample Kolmogorov-Smirnov Test = 3.426 - $p<0.001$). The actual species found are given in Appendix 1, which lists the number of broads in which each was recorded and the number of records for the two surveys.

Table 2. Showing the number of species and records from the combined sampling stations at each of the twenty of the broads for both surveys

Broad	No Samples	Species		Records		Average Species-richness	
		77	95	77	95	77	95
Hudson's Bay	8	17	53	36	168	4.5	21.0
Crome's	1	29	56	80	219	5.3	14.6
Blackfleet	5	9	31	28	79	6.0	16.0
Surlingham	1	19	43	38	122	3.5	11.1
Filby	9	25	39	78	150	8.7	16.7
Belaugh	1	14	32	22	108	1.8	9.0
Hoveton Little	1	13	44	32	122	2.7	10.2
Rockland	1	27	38	101	233	5.3	12.3
Hoveton Great	1	10	34	29	107	1.9	7.1
Ormesby	1	42	69	206	296	12.1	17.4
Malthouse	7	8	24	15	41	2.1	5.9
Ormesby Little	1	34	48	111	159	9.3	13.3
Burntfen	1	8	23	17	52	1.7	5.2
Ranworth	1	16	35	61	100	4.4	7.1
Martham South	9	13	25	45	62	5.0	6.9
Decoy	1	16	23	28	34	2.5	3.1
Alderfen	1	30	36	93	97	7.8	8.1
Rollesby	1	34	42	177	151	13.6	11.6
Lily	9	38	40	150	100	16.7	11.1
Upton	7	46	33	117	65	16.7	9.3
Average/broad	1	22	38	73	123	6.6	10.8

In 1977 the richest broads were the Trinity Broads and Upton Broad. The poorest lakes were mainly those in the Bure valley, particularly those located around the Wroxham and Ranworth areas.

By 1995, there had been a marked change in most of the broads and at some sites, such as Hudson's Bay and Belaugh Broad, this amounted to a four or fivefold increase in species-richness. The two broads on the River Yare - Rockland and Surlingham - showed twofold increases. On the River Ant, both

Crome's and Burntfen Broads showed large improvements, but Alderfen showed little sign of change. The Trinity Broads have remained in relatively good shape.

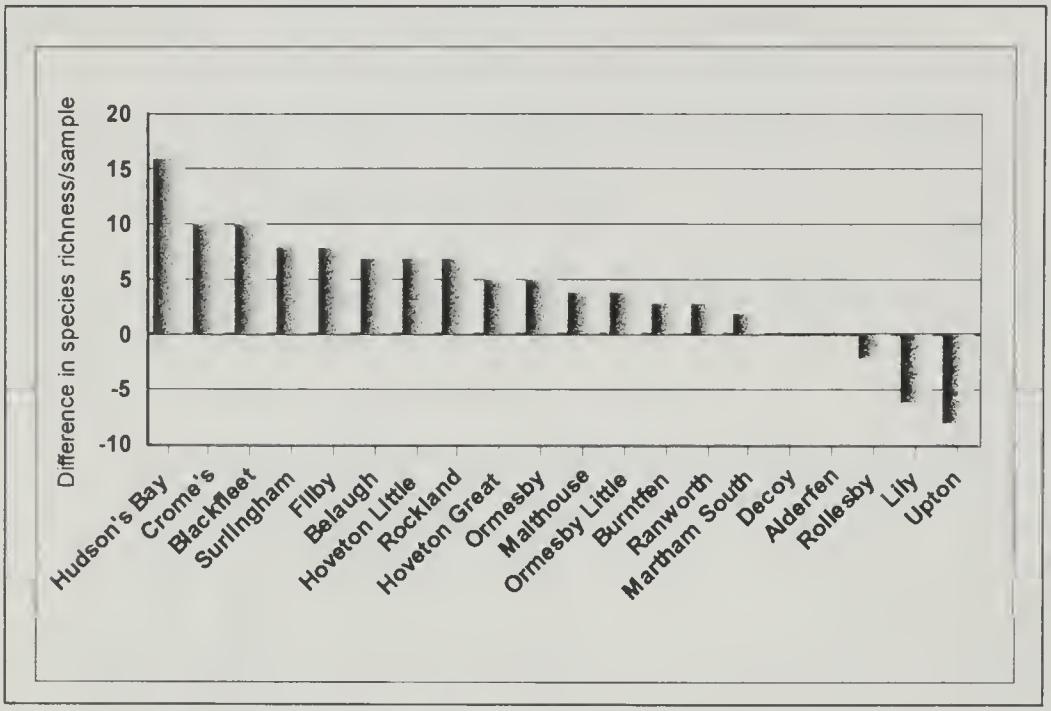

Figure 3. Changes in species-richness in each broad between 1977 and 1995

The differences in species-richness between the two surveys in each of the twenty different broads is shown in Figure 3. The broads are arranged in descending order of positive change. Three broads had decreased in species-richness. Upton Broad had undergone a surprising decline which may have been connected with the introduction of bream into the lake during the intervening period. It is also atypical in a number of other respects, such as the unusual quality of its sediments, and Upton Broad is therefore not included in the remaining analysis of the results.

To make the presentation of the results easier to decipher, the species can be conveniently divided into five groups. These are the molluscs, water bugs, crustaceans, leeches and the remainder of the insects (as well as the one spider, *Argyroneta aquatica*). For the purposes of simplicity I shall refer to the latter group simply as 'insects'.

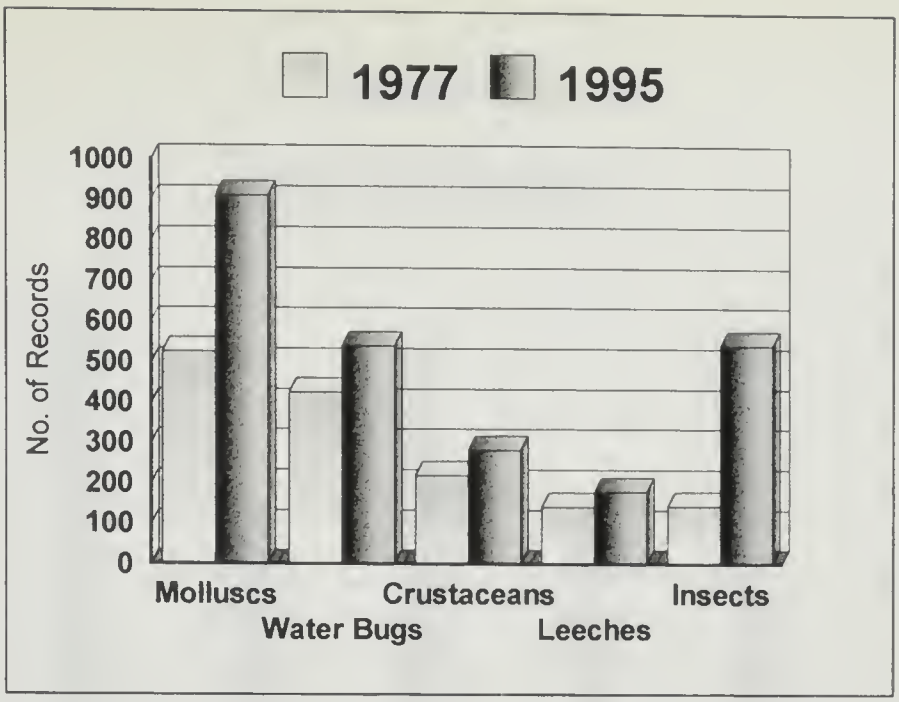

Figure 4. The number of records of species in the five main groups.

In both surveys, molluscs were the most prominent group, but water bugs were also common and widespread. Crustaceans tended to be found mostly in the more brackish lakes and leeches were recorded from numerous sites but usually from only one or two stations at a site. The insects, particularly the dragonflies, damselflies and water beetles were comparatively scarce in 1977 but were found at many new locations in 1995. The most striking differences between the two surveys was the number of records of molluscs and insects, but there were also marked variations between broads in different river systems.

The number of molluscs (Fig. 5) was higher in 1995 in every catchment apart from the Trinity system where the number of records was more-or-less the same in the two surveys. The difference in number of records is attributable to a number of species increasing their range. The list in Appendix 1 shows the full extent of these changes. For example, *Lymnaea stagnalis* was not recorded in 1977 but occurred in 6 broads in 1995; *Lymnaea auricularia* was found in only 4 broads in 1977 but in 14 in 1995; *Hippeutis complanatus* was found in 6 broads in 1977 and 15 in 1995 and all other planorbid snails also increase their range. In fact, of the 27 species of mollusc recorded, 24 occurred in more broads in 1995 than in 1977.

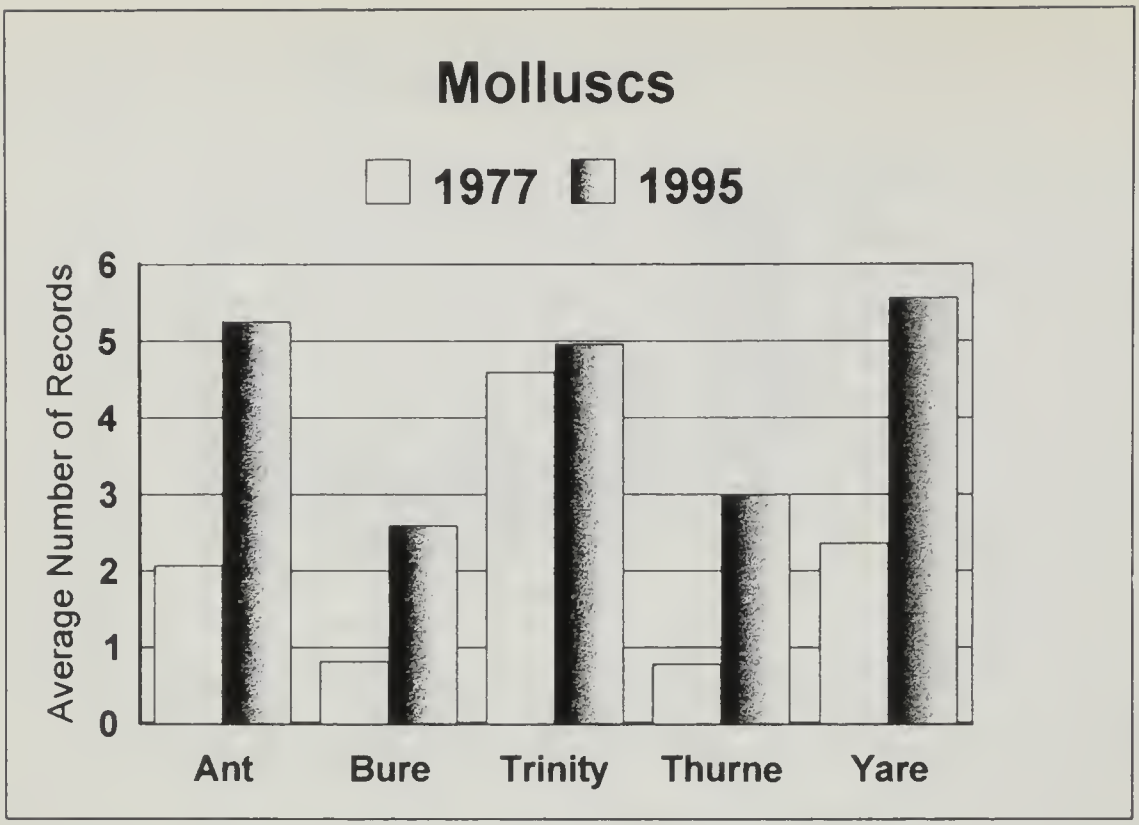

Figure 5. The average number of records of molluses per sample in the combined broads from each catchment

The water bugs showed fewer gains between the two surveys but again the numbers of records from the Trinity broads was about the same (Fig. 6). The full list shows that a number of species were only found in 1995, for instance *Cymatia coleoptrata*, which was recorded from 11 broads and the water stick-insect, *Ranatra linearis*, which was found in 8 broads. Eight other species of water bug occurred exclusively in the 1995 survey.

The other insects painted a rather different picture (Fig. 7). In every case the numbers were higher in 1995 than in 1977, and even in the Trinity Broads, the average number of records was almost three times that in 1977. The species which occurred in greater numbers were the blue and red damselflies (Coenagrionidae) and in particular the red-eyed damselfly (*Erythromma najas*), larvae of which were found in very large numbers in 1995. Among the dragon-

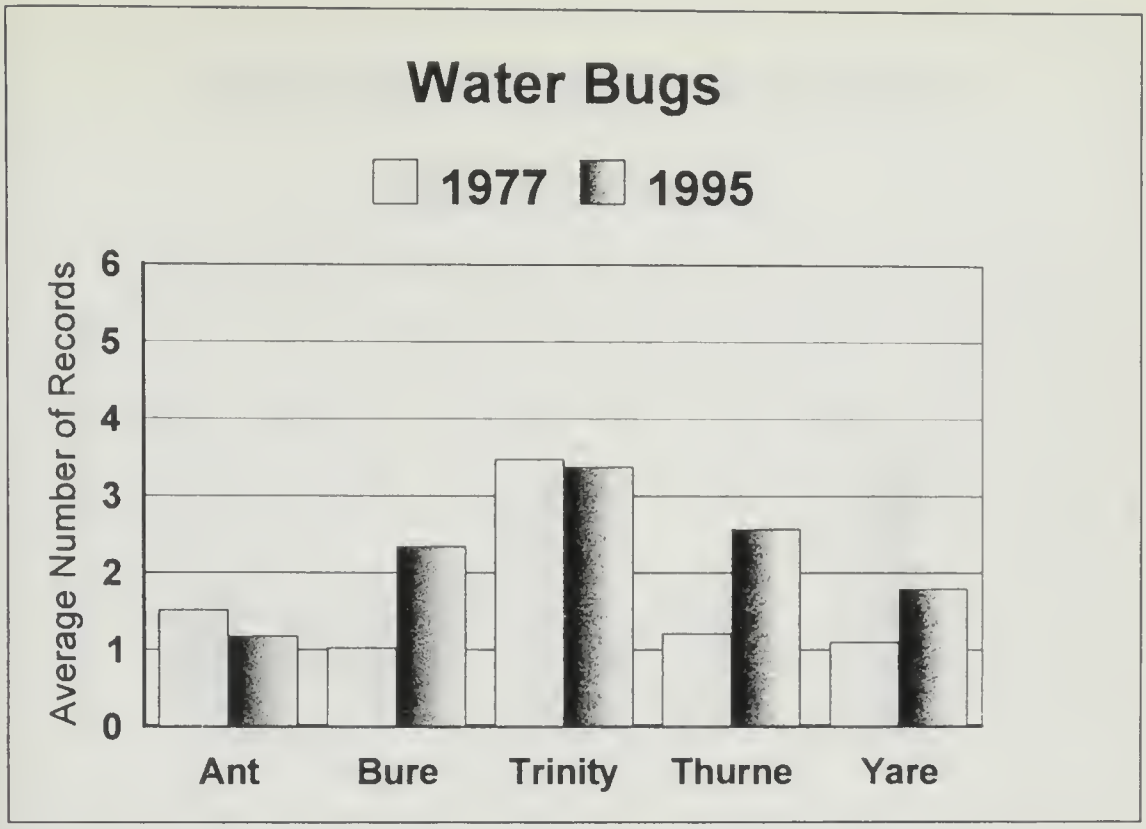

Figure 6. The average number of records of water bugs per sample in the combined broads from each catchment

-flies, larvae of the black-tailed skimmer (*Orthetrum cancellatum*) and the brown hawker (*Aeshna grandis*) were noted from a number of broads solely in 1995. The numbers of water beetles was also much higher in 1995, with one particularly rare species of whirligig beetle (*Gyrinus paykulli*) recorded from the Trinity Broads and at Alderfen Broad. There were also many more caddisflies and a number of records of spongefly larvae (*Sisyria* sp.): this together with a marked expansion in the ranges of various mayfly larvae and in particular those known to fishermen as the lake olive dun (*Cloeon dipterum*) and the angler`s curse (*Caenis horaria*).

The crustaceans and leeches showed few differences between the two surveys apart from in the Yare broads where the average number of records doubled in both cases. The amphipod, *Corophium curvispinum*, was recorded at six sites in 1995, registering a new species for Norfolk.

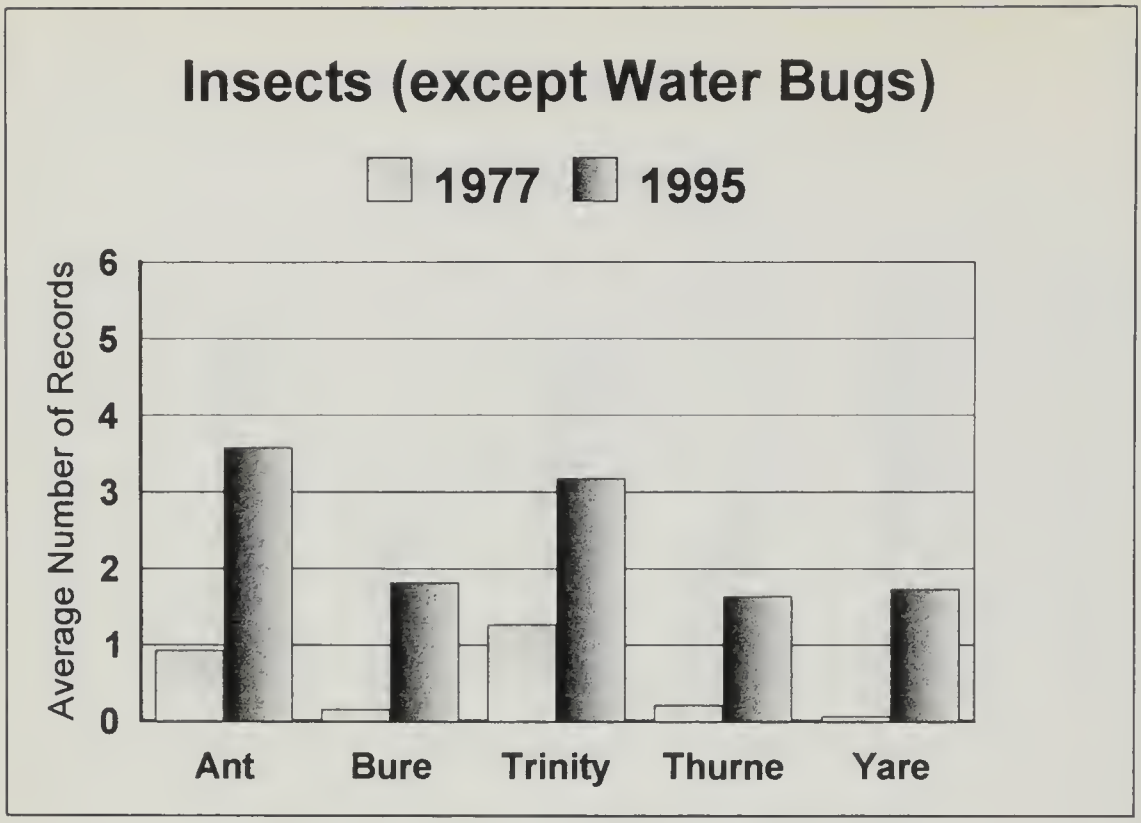

Figure 7. The average number of records of insects per sample in the combined broads from each catchment

The variation between broads in different catchments was partly a reflection of differences in the predominant habitats in each system. The Thurne broads, for example were mainly fringed by reed, whereas the Bure valley broads were largely bordered by carr and tall-herb vegetation. The Yare valley was once renowned for its extensive beds of reed sweet grass, *Glyceria maxima* (Lambert 1965), which was prevalent in 1977, but had almost completely disappeared by 1995. Figs. 8-10 illustrate the dissimilarities between the different principal habitat types and the changes in the macroinvertebrate communities. For comparative purposes the three bar-charts are drawn to the same scale.

The carr habitat was generally low in species-richness, but with water bugs the dominant group (Fig. 8). There were modest differences in numbers of species between the two surveys, but these were slight by comparison to the other habitats.

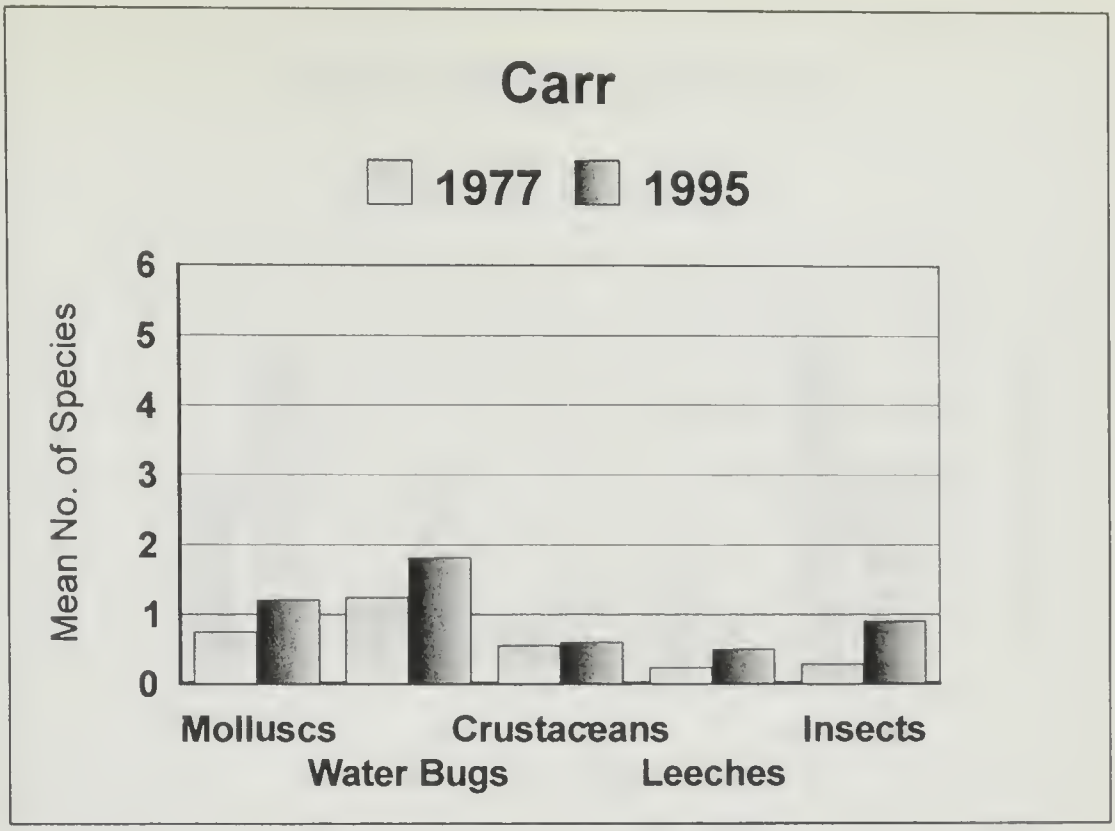

Figure 8. The average number of species in each group recorded from the carr habitat in the two surveys

The lilies showed some of the most striking dissimilarities between the two surveys (Fig. 9), in particular in the mollusc and insect groups, in which there were nearly three times as many representatives in the 1995 survey.

The differences in the snail assemblages in the lily beds were accounted for predominantly by dramatic changes in the pulmonate groups. A large proportion of these changes occurred in broads in the Bure valley particularly those connected to the main river, such as Belaugh Broad and Hudson's Bay, but there were also marked changes in the water lily communities in the Ant broads away from the main river, such as at Burntfen and Crome's Broads. The differences in the insect group were mainly in the damselflies, caddisflies and water beetles, but mayfly larvae were also more widespread in 1995. The Coenagrionidae were recorded mainly from the white water lily, *Nymphaea alba*.

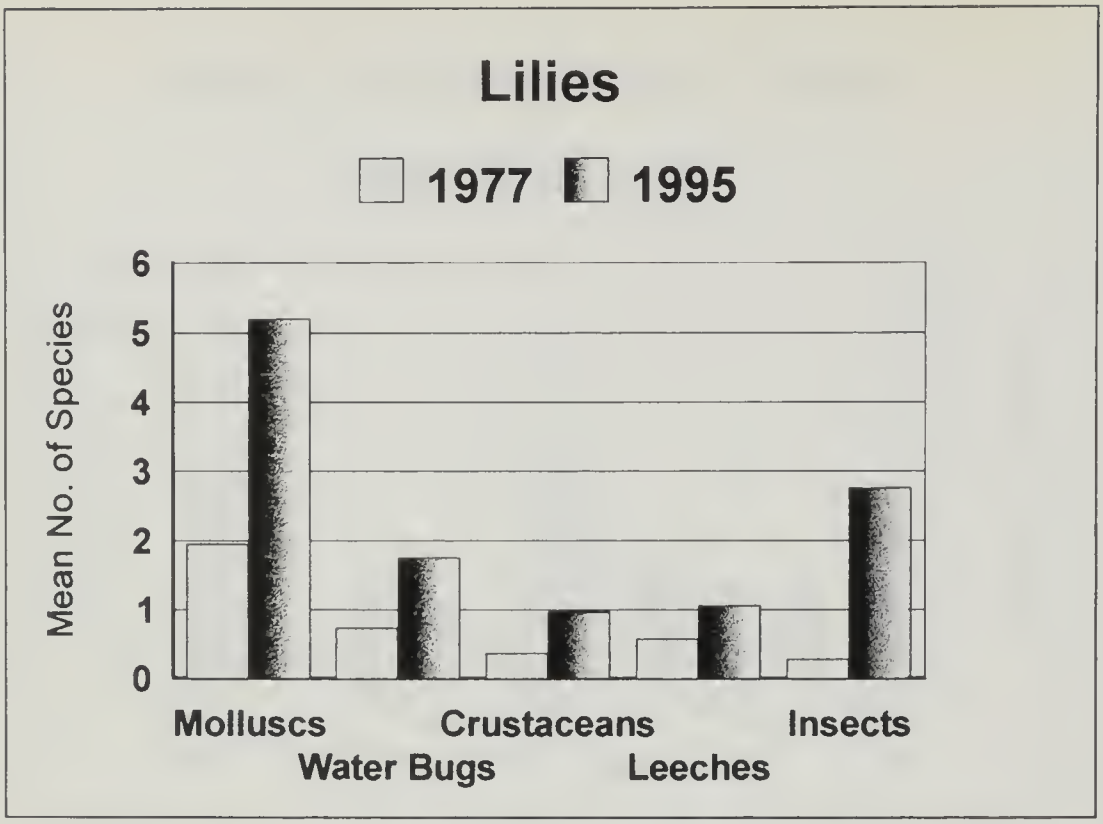

Figure 9. The average number of species in each group recorded from the lily habitat in the two surveys

The emergent habitats showed a marked change between the two surveys although in numeric terms the differences were not as pronounced as in the lily beds (Fig. 10). Nonetheless, the insect group had three times as many constituents and there were fifty percent more molluses in 1995. There were also a number of changes which are not shown up by the graph. For example, there were in fact considerable differences in the water bug communities between the two surveys. As mentioned earlier, the water stick-insect, *Ranatra linearis* was found only in 1995 at eight broads and in almost every case it was associated with the greater tussock sedge, *Carex paniculata*. The emergent habitats included a wide variety of meso-habitats and there were noticeable differences between these. For instance, *Schoenoplectus lacustris*, (common club-rush), and the various tall-herb plants harboured many more species than common reed. It was also clear that within the reedbed communities there were conspicuously more *Typha* spp. in 1995 than in 1977.

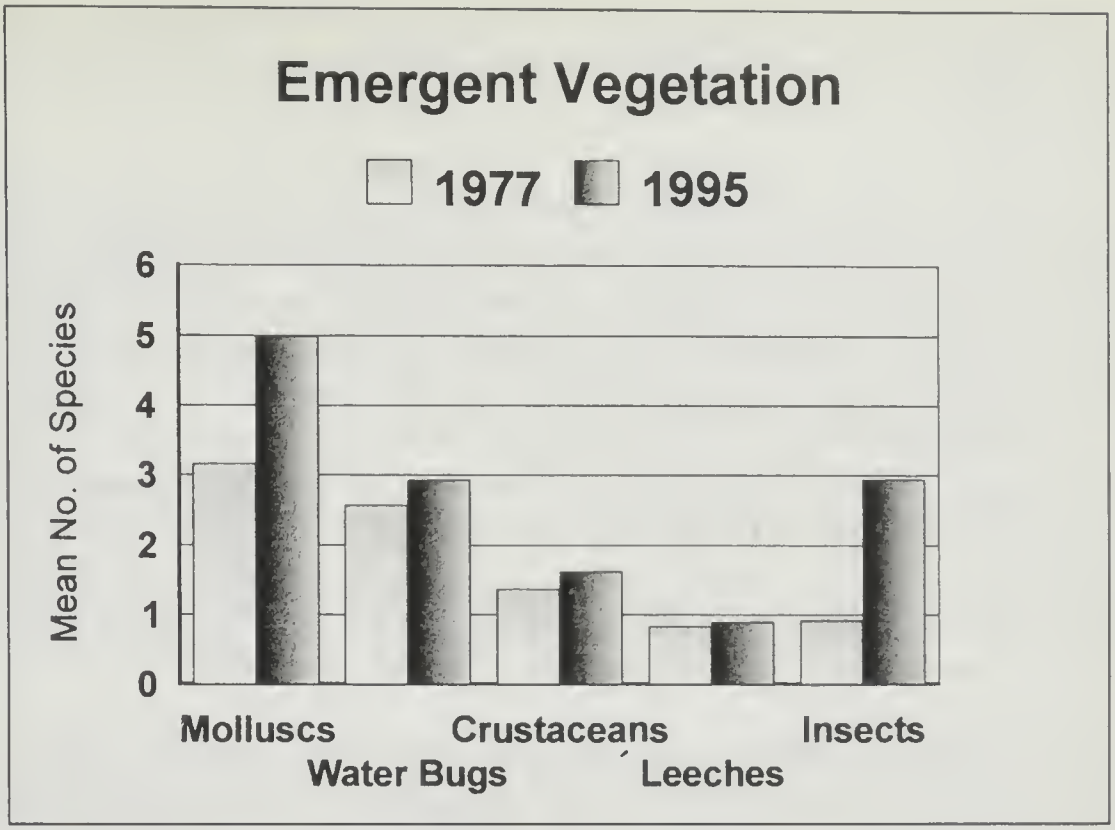

Figure 10. The average number of species in each group recorded from the emergent habitat in the two surveys

Discussion

At first glance it would seem reasonable to assume that the results reflect a general improvement in conditions since the late seventies. However, whilst invertebrates are noted for appearing in very large numbers one year, they can virtually disappear the next, so that single sampling occasions can be unreliable (Jackson 1997). Insects, in particular, are known to occur in greater abundance in very hot summers (Macan 1965). Furthermore, some authors have queried the validity of the hand-net as a suitable tool for collecting aquatic macroinvertebrates especially when studying such a variety of different habitats as found in the lake littoral. First, we must address the question of whether or not the results can be substantiated in any way to see if they actually reflect a fundamental increase in species-richness (and thus an improvement in conditions) or whether the two sets of results fall simply within the natural pattern of variation that might be expected of these animals. Finally, the validity of the sampling technique needs to be carefully scrutinised..

Certainly, it is unsatisfactory to have only two surveys separated by a twenty years, however, there were other studies which lend weight to the argument for improvement.

First of all, two small-scale studies were carried out in the late seventies, one by Driscoll in 1977 (Driscoll 1982) and the other by Watson in 1978 (AWA 1979) - they both studied littoral habitats and used broadly analogous methodology. Driscoll surveyed Rockland and Surlingham Broads and found six fewer species than the present study. Watson's survey covered five corresponding sites - Alderfen, Hoveton Great, Rockland, Surlingham and Upton. In all of these Watson recorded a fraction of the number of species that I found in 1977. For example, in Rockland Broad, he recorded only three species of mollusc compared to the 17 found in this study. Likewise, he found only 15 species at Upton Broad to my 48 species the year before. Thus, both studies confirm the poverty of macroinvertebrate communities in the late seventies.

Other corroborating evidence suggesting a general deterioration in conditions during the seventies comes from Ora Johannsson's work on damselflies at Upton and Alderfen Broads between 1972-74 (Johannsson 1976) in which she referred to a severe decline in odonate diversity, in particular at Alderfen, and catalogued the loss there of three species - *Erythromma najas*, *Enallagma cyathigerum* and *Coenagrion pulchellum*. Also at Alderfen, Wortley (1974) registered a marked decline in numbers of molluscs in the early seventies and cited the lack of macrophytes and changing nature of the sediment (rather than any changes in water chemistry) as the main reasons for their demise.

The next macroinvertebrate study was undertaken some fifteen years later - in the summer of 1990 (Kerrison and Phillips 1991). Like-for-like, they found 80 taxa (although some of these would have been more fully identified in my surveys) and as the comparisons in Table 3 show, at some sites, species-richness had already improved on the seventies results by the time Kerrison and Phillips carried out their survey. The difference at Hoveton Great Broad was particularly apparent.

They also noted the revival of species such as the water stick-insect (*Ranatra linearis*), the river neritc (*Theodoxus fluviatilis*) and the red-eyed damselfly (*Erythromma najas*).

Broad Surveyed	1977 (MJ)	1990 (KP)	1995 (MJ)
Filby	25	28	39
Hoveton Great	10	27	34
Martham South	13	18	25
Ormesby	42	43	69
Ranworth	16	23	35
Rollesby	34	35	42
Total for 20 broads	76	85-90 (est.)	108

Table 3. The species-richness recorded at six broads in 1977 and 1995 compared to Kerrison and Phillips' results in 1990.

The final piece of evidence pointing to a recent improvement in macroinvertebrate diversity, is demonstrated by the return of large bivalve molluscs to the River Yare. Between 1980 and 1987, the AWA carried out a number of surveys of a stretch of this river between Whitlingham and Cantley using a dredge to sample for bivalves. Their report (AWA 1987) stated that 'there was a surprising lack of the larger lamellibranch molluscs, such as *Unio pictorum* and *Anodonta cygnea'*. Driscoll (1982) also found no evidence of any large bivalves in his survey of the river. However, the most recent survey of the same stretch of river, carried out by Howlett and Baker (1998) showed that these animals were relatively common, with two other species, *Anadonta anatina* and *Pseudanodonta complanata* also being recorded in reasonable numbers.

Macrophyte surveys from 15 matching broads (Jackson 1983 and Dunsford 1996) revealed 57 records from 1977 compared to 66 records from 1995. *Hydrocharis morsus-ranae*, *Potamogeton friesii* and *Potamogeton obtusifolius* had all been reinstated since their earlier demise, whereas at least one species known to favour enriched conditions, *Potamogeton crispus*, was in decline by 1995. In general terms then, the aquatic macrophyte flora had increased in species-richness over the twenty years in a way which one would expect associated with an improvement in water quality (see Kennison, Dunsford and Schutten 1998) .

Annual and seasonal fluctuations in numbers of invertebrates are known to be commonplace. Peaks in insects, in particular, characteristically occur at unseasonably high air temperatures. High water temperatures may also affect the emergence of larval stages and lead to alterations in egg-laying behaviour of molluscs and crustaceans. In dragonflies, secondary peaks may arise as future generations, that hatched from eggs laid in the peak year, finally emerge from their long larval confinement. There may also be longer-term cycles, brought on by peculiarities in the populations dynamics of some species, such as those caused by alternating abundance of predators and prey.

Clearly, this study is not geared to measuring detailed temporal population trends. The most that could be hoped for was that the surveys would produce a reasonable reflection of the relative status of the littoral macroinvertebrate community at one moment in time. The 1977 survey was carried out the year after one of the hottest summers on record and 1995 was itself an extremely hot year. Both years, therefore, were probably favourable for the majority of macro-invertebrates. Seasonal differences tend to manifest themselves by differences in abundance rather than changes in species-richness and to compensate for this, samples were deliberately taken in the same season. Despite this precaution, in over half the broads surveyed, twice the number of species of macroinvertebrate were recorded in 1995. The magnitude of this difference would be very difficult to explain in terms of seasonal fluctuations alone. Also, if annual or cyclical processes were at work, it is unlikely that they would coincide in such a way that so large a proportion of the community would be affected simultaneously. With the string of record temperatures over the past decade however, it is impossible to rule out some climatic influence.

The sampling technique was generally accepted as the most satisfactory method for undertaking a survey of this kind, particularly for studying species-richness (Jackson 1997 and Biggs *et al* 1998). The hand-net however is liable to under –score fast moving animals and those that are able to cling stubbornly to the vegetation, but these are consistent drawbacks common to both the surveys. The change in method between the two surveys, however, does need further explanation. On the surface, it might appear that by retrieving the entire catch in 1995, instead of taking only voucher specimens as in 1977, that a disproportionately high number of species might have been recovered. In fact, there are a number of reasons why the opposite may actually have been the case.

Firstly, in 1977, special attention was paid to groups that were more awkward to identify and a proportionately larger number of these specimens were kept. Secondly, many of the new species found in 1995 would have been all but impossible to have overlooked in 1977, such as the odonate larvae and the large gastropods. Lastly, the sampling intensity was comparatively high for a study of this kind, but crucially also, sampling effort was much greater in 1977 particularly at sites which looked the most promising. For example, Hudson's Bay was searched for a whole day in 1997 and yet only 17 species were found, in 1995 the same broad was sampled for only eight minutes and 53 species were caught!

Taken together, the veracity of the sampling method, the findings of the macrophyte surveys and the corroborative macroinvertebrate evidence provide a strong argument that there had indeed been a significant increase in macroinvertebrate species-richness between 1977 and 1995. If we take this to be the case, then it is germane to ask what it was that had caused the decline in the first place and why there had been a subsequent improvement?

In 1977 molluscs were scarcest in broads directly connected to the main rivers, yet the Trinity Broads, which are free from motor boats and are isolated from the main boating channel, maintained healthy molluscan communities. 1977 and Insects, on the other hand, seem to have been affected equally in all broads (Fig. 7). Another prominent finding was that although the emergent habitats were consistently the richest and carr the poorest, the most significant changes had occurred in the water lily community.

Beds of water lilies would be expected, even under reasonably enriched conditions, to be teeming with aquatic life, because the structure of the plants offers many benefits in the struggle for survival, such as a refuge from predation by fish, an abundant food source (mainly from the periphyton), perching sites and substrate for egg-laying (Jackson 1997). The fact that in 1977 there were so few species, even where macrophytes were abundant (and this was particularly evident in the River Bure and Yare broads) leads us to speculate that there was some other reason for their absence. The three top contenders are water chemistry, sediment dynamics and the presence of predatory fish or waterfowl.

Evidence that there may have been sizeable changes in fish communities in the late seventies is in the process of being compiled (M.Perrow pers. comm.) and this might yet prove to have some bearing on the demise of molluscs. Tench, *Tinca tinca*, for example, are known to feed extensively on molluscs, but they feed mainly in the sediments and are poorly adapted to feeding amongst dense vegetation. Perch, *Perca fluviatilis*, do feed amongst weedbeds, but only take very small molluscs in their first year-or-two before switching to becoming piscivores. Most of the other fish in the broads feed predominantly on zooplankton or on each other. It is unlikely therefore that fish would have been directly responsible for such a severe decline in littoral mollusc populations. Little is known about the effects of predatory waterfowl, such as tufted duck *Aythya fuligula*, in the broads but they are unlikely to be very effective predators in marginal vegetation and amongst water lilies.

As far as water chemistry is concerned, in the past twenty years there have been numerous improvements to the sewage treatment works that discharge into the system and this has without doubt reduced both the source of much of the nutrient enrichment and the rate of sediment accumulation in many of the broads. Many of the species that were absent in 1977, such as *Lymnaea stagnalis* and most planorbid snails, are not known for their sensitivity to excessive nutrient enrichment. Less tractable chemical influences have received less attention, such as various pesticides and herbicides which we know have entered the watercourse. One such chemical TBT (Tributylin), a molluscicide component of antifouling paints extensively used to paint hulls of motor cruisers from the late sixties onwards, may have had a more direct effect on aquatic systems.

TBTs were developed originally to try to eradicate schistosomiasis or bilharzia, a highly infectious trematode disease carried by freshwater snails from the genus *Biomphalaria*. These happen to be herbivorous snails that feed mostly off periphyton or macrophytes and are favoured by dense weed beds, of plants like *Ceratophyllum demersum* (Moss 1980). One species called *Biomphalaria glabrata* was found to exhibit reduced egg-laying capacity at concentrations of TBT as low as $1ngl^{-1}$ or 1 part per thousand millionth (Waite *et al* 1989). Numerous studies have also shown that marine gastropods and bivalves are also particularly sensitive to TBT (e.g. Loretto *et al* 1994). Findings such as these led Golberg (1986) to describe TBT as "the most toxic substance ever delib-

-erately introduced into natural waters".

Kerrison and Phillips studied the effects of TBT on three species of mollusc – *Bithynia tentaculata, Anisus vortex* and *Lymnaea peregra* – in a series of enclosure experiments in Hoveton Great Broad in the late eighties (Kerrison 1988 and 1989). The results showed that exposure for eleven weeks to low TBT concentrations (averaging less than 200ngl^{-1} but peaking at 600ngl^{-1}) was lethal to *Anisus vortex* and caused 80% mortality in *Bithynia tentaculata* and *Lymnaea peregra*. Egg deposition was also virtually eliminated at these concentrations. The reduction in snail numbers led to an increase in periphyton biomass compared to the control enclosures and also to increased colonisation of the aquatic macrophyte stems and leaves by tube-building chironomids, particularly *Chironomus plumosus*. Thus, not only was shading of the plants increased due to higher periphyton biomass, but also the area of photosynthetic tissue was reduced due to the construction of chironomid tubes and associated detritus accumulation.

Kerrison (1988) recorded spring levels of TBT in the River Bure near Hoveton Great Broad of between 200 and 700ngl^{-1}. Another study of TBT concentrations in the River Bure in the late eighties confirmed these findings (Waite *et al* 1989). It showed that although subsurface levels (taken at 10cm depth) were very low upstream of Wroxham (averaging 2-3ngl^{-1}), at sixteen sampling stations from Wroxham to Horning TBT levels averaged 235ngl^{-1} with some of the highest concentrations being found in the broads, for example one sample in Wroxham Broad measured 900ngl^{-1}. The level of TBT found in the River Yare proved it was even more contaminated than the open stretches of the River Bure. At Brundall, TBT levels exceeded 370ngl^{-1} in June 1986 and 230ngl^{-1} in June 1987. At the Brundall Marina the highest level of all ws recorded at 3260ngl^{-1} in June 1986 (Waite *et al* 1989). Such concentrations would certainly have caused high mortalities in the three molluscs that Kerrison studied and would have eliminated egg production. In all probability the whole mollusc community would have been equally adversely affected. In fact, concentrations were found to be higher still in the surface microlayer in Wroxham Broad (Clearly & Stebbing 1987) suggesting that species such as the Lymnaeids would have been extremely vulnerable because of their habit of skimming along under the surface film. It is interesting to note that there are very few neustonic (living on the surface film) organisms caught in either

survey, particularly in 1977, and this might be attributable to the highly toxic nature of the surface microlayer. In addition, the organotin residues would probably have accumated in higher concentrations in backwaters with only slow flushing rates – such as Hudson's Bay where the surveys happen to show the highest increase in mollusc records bewteen 1977 and 1995.

The consequence of the loss of large numbers of molluscs from the system might have been very severe. Molluscs are known to play a vital role in keeping filamentous algae at bay and it has been shown experimentally that the presence of gastropds enhances the growth rates of aquatic plants (Underwood *et al* 1992). The loss of littoral molluscs might have literally foreshadowed the loss of submerged aquatic plants in the broads.

Because of the potential damage to shellfish fisheries in enclosed estuaries, antifouling paints containing TBTs were banned from use in the UK on vessels of less than 25m in length in 1987 (ENDS report 1999). Larger seagoing craft, however, were still permitted by law to be treated with TBT paint. It is perhaps no coincidence therefore, that the banning of the use of these paints on the broadland pleasure cruiser fleets coincided with a gradual comeback for molluscs in the broads.

There has been a considerable development over the past twenty years in our understanding of the underlying reasons for the sudden deterioration of the broadland ecosystem that occurred in the latter part of this century (Moss *et al* 1996, Madgwick and Phillips 1996, Perrow *et al* 1997 and Scheffer 1998). Reductions in nutrient loading combined with removal of sediments and fish biomanipulation has resulted in submerged macrophytes being restored to a number of broads over the past 20 years (Schutten *et al* 1997), but progress has been painfully slow and this may be partly because too much emphasis was originally placed on the effects of nutrients on phytoplankton and not enough effort was put into studying biotic interactions, higher up the food chain. (Scheffer 1998) This is, of course, easy to say in hindsight, but in all these endeavours macroinvertebrates have received little or no attention, apart from where they have taken over as major zooplankton predators after the removal of fish populations (Irvine *et al* 1993). For example, only recently has any real credence been given to the possibility that gastropod herbivores may have played an important role in the growth of submerged plants. Now there is also

increasing evidence to show that macroinvertebrates may play an essential role through the provision of sufficiently high protein food in stabilising the system following biomanipulation for young-of-the-year perch to boost their growth rates enough to enable them to reach a piscivorous stage in time to control young cyprinids hatched in the same year. Macroinvertebrates also provide a rich protein source for waterfowl chicks. This study has highlighted the importance of keeping a close eye on the macroinvertebrate community and it is hoped that much more attention will be paid to these animals in future studies.

Conclusion

It seems reasonable to conclude that the numbers of species of aquatic macroinvertebrate have increased markedly in most broads since the late seventies – this has manifested itself chiefly in higher numbers of molluscs and insects. The emergent habitats proved to be the most diverse whereas carr was the most impoverished. The floating-leaved habitat fell between these extremes but had undergone the most substantial change between the two surveys. The worst declines in the mollusc communities appeared to have occurred in broads connected to the main river channels and close to the busy holiday traffic from broadland pleasure cruisers. There was strong circumstantial evidence to suggest that the decline was caused by residues of TBTs leaching from the hulls of boats painted during the seventies and eighties that had concentrated in the surface layers and accumulated in backwaters, such as Hoveton Great Broad. These isolated basins acted as settlement lakes for TBT residues of which can still be detected in the sediments today.

Other factors that may have played a part in changes in the status of the macroinvertebrate community are climate, changes in fish and bird populations, pesticides and nutrient enrichment. Much more research needs to be done into the part played by the macroinvertebrate community in shallow lakes ecosystems before the relative importance of each of these factors can be reasonably established.

The recovery of the Broads is undoubtedly well under way, but the gains have been modest considering the very rich diversity of open water habitats that we know were once such a characteristic feature of these lakes. The littoral

habitats which flourished throughout the broads at the turn of the century had literally hundreds more species than are present today and they probably would have rivalled even the richest aquatic communities of the grazing marsh drainage systems, which may nowadays have two or three times as many species as the best sites in the broads. I hope that the results of this survey will help to shed a little more light on future management practices and speed the arrival of the day when the peace and tranquility of the broads can be fully restored for all of us to enjoy.

Appendix. List of macroinvertebrates

Species	Authority	GB Status	Number of Broads		Number of Records	
			1977	1995	1977	1995
Molluscs:						
Acroloxus lacustris	(L.)	*Common*	12	15	53	38
Anisus leucostoma	(Millet)	*Common*	0	1	0	1
Anisus vortex	(L.)	*Common*	8	14	27	47
Armiger crista	(L.)	*Common*	1	6	2	25
Bathyomphalus contortus	(L.)	*Local*	7	6	8	13
Bithynia leachii	(Sheppard)	*Local*	9	15	38	62
Bithynia tentaculata	(L.)	*Common*	13	18	67	111
Dreissena polymorpha	(Pallas)	*Naturalised*	0	2	0	2
Gyraulus albus	(Muller)	*Local*	15	18	70	113
Hippeutis complanatus	(L.)	*Local*	6	15	10	34
Lymnaea auricularia	(L.)	*Local*	4	14	6	68
Lymnaea palustris	(Muller)	*Common*	2	6	3	10
Lymnaea peregra	(Muller)	*Common*	18	17	68	73
Lymnaea stagnalis	(L.)	*Common*	0	6	0	19
Lymnaea truncatula	(Muller)	*Common*	0	1	0	1
Physa fontinalis	(L.)	*Common*	11	16	29	48
Planorbarius corneus	(L.)	*Common*	0	1	0	1
Planorbis carinatus	Muller	*Common*	5	14	17	44
Planorbis planorbis	(L.)	*Common*	7	9	8	11
Potamopyrgus antipodarum	(Gray)	*Naturalised*	12	18	26	73
Sphaerium corneum	(L.)	*Common*	6	7	18	14
Sphaerium lacustre	(Muller)	*Common*	3	4	7	4
Theodoxus fluviatilis	(L.)	*Local*	1	4	1	6
Valvata cristata	Muller	*Local*	5	12	8	23
Valvata macrostoma	Morch	*RDB2*	0	2	0	2
Valvata piscinalis	(Muller)	*Local*	15	17	60	71
Viviparus contectus	(Millet)	*Local*	1	0	1	0
Crustaceans:						
Argulus foliaceus	(L.)	*Common*	7	9	7	13
Asellus aquaticus	(L.)	*Common*	10	16	41	92
Asellus meridianus	Racovitza	*Common*	8	14	25	38
Corophium curvispinum	Sars	*Naturalised*	0	6	0	16
Corophium multisetosum	Stock	*Notable/Nb*	0	4	0	6
Crangonyx pseudogracilis	Bousfield	*Naturalised*	11	16	59	70
Gammarus zaddachi	Sexton	*Common*	9	8	50	31
Neomysis integer	(Leach)	*Common*	3	3	18	3
Palaemonetes varians	(Leach)	*Common*	5	2	11	6
Sphaeroma hookeri	Leach	*Common*	2	1	11	9

Species	Authority	GB Status	Number of Broads		Number of Records	
			1977	1995	1977	1995
Mayflies:						
Caenis horaria	(L)	*Common*	2	9	2	19
Caenis robusta	Eaton	*Nr*	0	7	0	8
Centroptilium luteolum	(Muller)	*Local*	0	1	0	2
Cloeon dipterum	(L)	*Common*	9	17	22	98
Cloeon simile	Eaton	*Local*	1	1	1	3
Dragonflies and Damselflies:						
Aeshna cyanea	(Muller)	*Common*	0	2	0	2
Aeshna grandis	(L)	*Common*	0	3	0	7
Coenagrionidae spp.	.....	.....	8	17	25	74
Libellula quadrimaculata	L	*Common*	0	2	0	2
Orthetrum cancellatum	(L)	*Local*	0	3	0	4
Erythromma najas	(Hansemann)	*Local*	2	14	2	45
Alderflies and Spongeflies:						
Sialis lutaria	(L)	*Common*	3	7	5	10
Sisyria sp.	.....	.....	1	5	1	10
Water Spider:						
Argyroneta aquatica	(Clerck)	*Local*	5	8	8	17
Water Bugs:						
Callicorixa praeusta	(Fieber)	*Common*	8	13	46	42
Corixa dentipes	(Thomson)	*Local*	1	5	1	7
Corixa panzeri	(Fieber)	*Local*	6	3	15	4
Corixa punctata	(Illinger)	*Common*	8	7	11	15
Cymatia coleoptrata	(Fabricius)	*Local*	0	11	0	60
Gerris argentatus	Schummel	*Local*	0	2	0	4
Gerris lacustris	(L)	*Common*	0	3	0	3
Gerris odontogaster	(Zedderstedt)	*Common*	2	1	2	1
Hesperocorixa linnei	(Fieber)	*Common*	0	2	0	4
Hesperocorixa sahlbergi	(Fieber)	*Common*	1	0	1	0
Hydrometra stagnorum	(L)	*Common*	1	0	1	0
Ilyocoris cimitoides	(L)	*Common*	3	5	5	10
Mesovelia furcata	Mulsant & Rey	*Local*	0	3	0	5
Nepa cinerea	L	*Common*	1	1	3	1
Notonecta glauca	L	*Common*	7	10	7	23
Notonecta maculata	Fabricius	*Local*	0	3	0	4
Notonecta marmorea viridis	Fabricius: Delcourt	*Common*	0	3	0	6
Plea minutissima	Leach	*Common*	0	1	0	1
Ranatra linearis	(L)	*Local*	0	8	0	18
Sigara concinna	(Fieber)	*Local*	2	5	3	8
Sigara distincta	(Fieber)	*Common*	9	13	57	58
Sigara dorsalis	(Leach)	*Common*	20	18	112	121
Sigara falleni	(Fieber)	*Common*	18	18	156	129
Sigara fossarum	(Leach)	*Common*	0	4	0	5
Sigara lateralis	(Leach)	*Common*	4	4	4	9
Sigara stagnalis	(Leach)	*Common*	2	1	2	4
Leeches:						
Erpobdella sp.	.....	.....	5	3	13	4
Erpobdella octoculata	(L)	*Common*	5	7	6	15
Erpobdella testacea	(Savigny)	*Local*	0	6	0	8
Glossiphonia complanata	(L)	*Common*	10	7	13	14
Glossiphonia heteroclita	(L)	*Local*	4	7	4	18
Helobdella stagnalis	(L)	*Common*	12	15	38	64
Hemiclepsis marginata	(Muller)	*Local*	2	4	3	8
Pisicola geometra	(L)	*Common*	8	8	20	16
Theromyzon tessulatum	(Muller)	*Common*	15	16	46	34

Species	Authority	GB Status	Number of Broads		Number of Records	
			1977	1995	1977	1995
Caddisflies:						
Agraylea multipunctata	Curtis	*Common*	0	6	0	37
Agrypnia sp.	-------	-------	0	1	0	1
Agrypnia pagetana	Curtis	*Local*	2	6	2	9
Anabolia nervosa	(Curtis)	*Common*	1	2	1	2
Athripsodes aterrimus	(Stephens)	*Common*	2	9	2	24
Cyrnus flavidus	McLachlan	*Local*	6	2	18	11
Limnephilus marmoratus	Curtis	*Common*	0	1	0	1
Holocentropus dubius	(Rambur)	*Common*	2	0	3	0
Molanna angustata	Curtis	*Common*	0	1	0	2
Mystacides longicornis	(L.)	*Common*	3	0	4	0
Oecetis lacustris	(Pictet)	*Common*	1	0	1	0
Phryganea bipunctata	Retzius	*Common*	0	1	0	1
Plectrocnemia conspersa	(Curtis)	*Common*	0	3	0	3
Plectrocnemia geniculata	McLachlan	*Common*	0	1	0	1
Polycentropus flavomaculatus	(Pictet)	*Common*	0	6	0	15
Tinodes waeneri	(L.)	*Common*	2	5	2	10
Water Beetles:						
Cercyon marinus	Thomson	*Local*	0	1	0	1
Dryops luridus	(Erichson)	*Common*	0	1	0	1
Enochrus melanocephalus	(Olivier)	*Notable/Nb*	0	3	0	3
Enochrus testaceus	(Fabricius)	*Local*	0	4	0	4
Gyrinus sp.	-------	-------	5	8	12	15
Gyrinus marinus	Gyllenhal	*Common*	1	5	1	9
Gyrinus paykulli	Ochs	*Na*	1	5	1	6
Haliplus sp.	-------	-------	3	1	3	1
Haliplus confinis	Stephens	*Common*	1	0	1	0
Haliplus fluviatilis	Aube	*Common*	0	1	0	1
Haliplus lineatocollis	(Marsham)	*Common*	0	1	0	2
Haliplus lineolatus	Mannerheim	*Local*	0	1	0	1
Haliplus wehnckei	Gerhardt	*Local*	0	2	0	7
Hydrophilidae sp.	-------	-------	1	0	1	0
Hygrotus inaequalis	(Fabricius)	*Common*	1	4	1	5
Hyphydrus ovatus	(L.)	*Common*	5	10	9	21
Laccobius biguttatus	Gerhardt	*Local*	2	4	2	6
Laccobius bipunctatus	(Fabricius)	*Common*	0	1	0	1
Laccophilus hyalinus	(Degeer)	*Common*	0	4	0	8
Laccophilus minutus	(L.)	*Local*	1	1	1	1
Noterus clavicornis	(Degeer)	*Local*	5	13	13	28
Noterus crassicornis	(Mueller)	*Notable/Nb*	0	2	0	3
Plateumaris sp.	-------	-------	1	0	1	0
Stictotarsus duodecimpustulatus	(Fabricius)	*Local*	1	0	1	0
Moths:						
Nymphula nymphaeata	L.	*Common*	0	2	0	2
Number of Taxa/Records in each year			**84**	**117**	**5418**	**6455**
Number of Species in each year			**75**	**111**		

Total Number of Species = 119

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DARK BUSH-CRICKET *PHOLIDOPTERA GRISEOAPTERA* (De GEER): FIRST FENLAND RECORD

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Pholidoptera griseoaptera is widely distributed in East Norfolk, where its brisk chirps can be heard from brambles and nettles from July to October. Because of its flightless nature, its range tends to be continuous, and the boundaries of its distribution are abrupt (*Transactions Norfolk Norwich Nats.* Soc. **30** (1). The author was therefore surprised to discover an isolated colony on the west bank of the River Great Ouse where it is crossed by the Ely to King's Lynn railway line at Ten Mile Bank (TL 592-986). A single nymph was spotted by chance in spring 1998, during research into the distribution of the slender groundhopper (*Tetrix subulata* L.). A return visit in the autumn revealed a substantial colony along 200m of roadside verge to the east of the bridge and 200m of railway bank to the south. It was also present in rank vegetation at the water's edge. Although remote from other Norfolk colonies the site's 10km square is contiguous with the Cambridgeshire population, from which the railway is a probable vector for introduction, either through imported soil in the construction of embankments, or by natural colonisation along the linear habitat of the railway.

TUFA IN RIDGES AT LEZIATE FEN

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Aerial photographs of Leziate Fen in West Norfolk show a series of parallel ridges running north-south in the northern half of the Fen. Superficially these look like ridge and furrow caused by medieval ploughing. However, this is rare in East Anglia, the few examples are mostly along the Fen edge at Hilgay. Seen on the ground these ridges are very obvious and are much steeper and narrower than ridge and furrow. When rabbit scrapes on the banks are examined they show lumps of tufa, often 20cm or larger, with apparent plant remains embedded in them. This material is fairly hard though will eventually break up into small pieces if exposed. It does supply sufficient calcium carbonate to allow the ridges to support a vegetation with some chalk-loving plants.

The origin of the ridges and the tufa is uncertain but Clarke (1918) describes active peat working in his paper. The site itself is on the greensand but close to the boundary with the chalk to the east where presumably the calcium carbonate originated to form the tufa. Leziate Fen, together with Sugar and Derby Fens suffered from massive drainage works involving the straightening of the Gaywood River. This probably began in or before the second world war though the sites still supported rich fen communities in 1948 when described by Charles Petch (1948) and was completed by c.1971 to judge from aerial photographs held by the Norfolk archaeological unit at Gressenhall. There were probably progressive changes to the drainage particularly between 1950 and 1964, so that in 1954 Swann (*in litt.*, 1956). could talk about walking on the fen in gym shoes rather than gum boots. These sites are still SSSIs but have changed considerably from when they were first designated.

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FRESHWATER CLADOCERA: WHEATFEN BROAD

Norfolk & Norwich Naturalists' Society Microscopy Group Research Committee Report

Cladocera are almost exclusively inhabitants of freshwater. A few species are planktonic in open waters but the majority are found in ponds and ditches or in the weedy margins of large open waters. In the early years of the 20th century the Norfolk naturalist Robert Gurney made extensive surveys of the waterfleas of the broads of the mid-Yare river valley. He concentrated his work on Surlingham and Rockland Broads and his studies were recorded in the *Transactions* and in his diaries held at the Castle Museum.

The Society's Research Committee, working through the Microscopy Group, initiated a three year programme to examine the waterflea populations of Wheatfen Broad and to use their data to make comparisons with the records of Gurney nearly one hundred years earlier. The Microscopy Group made regular monthly field visits to Wheatfen and they also held a one day workshop in Norwich which focused on the techniques of collection, microscope preparation and identification of Cladocera.

Wheatfen is a tidal freshwater reserve which includes open waters, tidal dykes, non-tidal dykes and turf ponds. Many of the dykes are reed fringed but a number run along the edges or through mixed woodland. They thus offer a range of habitats for waterfleas. There are no records of Cladocera for Wheatfen other than those of recent years. The field visits focused on a number of broad aims:-

1. The local distributions of Cladocera both between and in dykes.

2. The distribution of Cladocera throughout the reserve. The tidal open waters of Wheatfen Broad, Deep Water, Fen Channel and the Pool can be contrasted with the tidal waters of Home, Penguin, Crake's and Middle Marsh Dykes. Non-tidal dykes include Boundary Dyke and Smee Lake Dyke. The woodland dykes include the Sluice and Ingold Dykes. The latter is currently being cleared of some overhanging trees and scrub. There are three turf ponds on the reserve:

Thatch Pond was excavated in 1990; Osier Carr Pond in 1994 and Alder Carr Pond in1997.

3. Population changes within and between species throughout the year to gain an understanding of the population dynamics of the group.

4. The colonization of newly created dykes. In 1997 a dyke was dredged on the boundary between Crake's Marsh and Thack Marsh. On one side it is bordered by reed and on the other by varying levels of sallow carr. The latter shades some stretches of the water. This may be a limiting factor in the distribution of cladocerans in this tidal dyke.

Family Sididae

Sida crystallina Müller. A common species in the tidal waters of the Fen Channel leading to Rockland Broad. Frequently found attached to water lily leaves.

Family Daphniidae

Simocephalus vetulus Müller. A very common species of both tidal and non-tidal channels and dykes as well as turf ponds. In March 1997 it was the only species of cladoceran noted and in one non-tidal dyke it was abundant by June 1997 to the exclusion of all other species. Recorded by R.Gurney in Surlingham and Rockland Broads, September 1903. R. Gurney Surlingham Broad October 1920 and May 1921 as being common.

Simocephalus exspinosus (Koch). Collected in the tidal Home Dyke on 26th September 1997. It has been previously recorded by Gurney in Norfolk in 1903.

Daphnia pulex (de Geer). A sudden emergence of populations of this waterflea occurred in the non-tidal Smee Loke dyke in 1995. It was only noted at this time and there has been no subsequent evidence of its presence in other years.

Daphnia hyalina Leydig var. *lacustris* Sars. A species collected in 1994 in both Osier Carr and Thatch Ponds

Daphnia longispina O.F.Müller. Recorded in turf ponds, non-tidal dykes and

tidal dykes/channels. Previously recorded by R.Gurney June 1903 in Rockland and Surlingham Broads

Daphnia cucullata Sars. Found in Osier Carr Pond in August 1994. Previously only recorded from Breydon Water in 1920 by R.Gurney (1929).

Daphnia obtusa Kurz.. Recorded in July 1995 in the non-tidal Smee Loke Dyke.

Ceriodaphnia pulchella Sars. Recorded in tidal dykes and channels amongst starwort and sweet flag.. Recorded by R. Gurney from Rockland and Surlingham Broads 1903.

Scapholeberis mucronata O.F.Müller. Collected from both non-tidal and tidal dykes. This is one of a small group of crustaceans which depend on rows of bristles which lie in the plane of the surface to suspend themselves from the water film. Members of this genus are the only truly neustonic waterfleas. Recorded by R.Gurney from Rockland Broad and Surlingham Broad 1903.

Family Bosminidae
Bosmina longirostris Müller. An occasional species in Fen Channel May-July 1994 and in Deep Waters amongst sweet flag September 1997. Recorded by R.Gurney in Rockland Broad June 1903.

Family Macrothriciidae
Macrothrix laticornis Jurine. Collected in Osier Carr Pond. July 1994. An interesting discovery in this pond which was dug only in that year.

Family Chydoridae
Chydorus sphaericus Müller. Recorded from turf ponds, non-tidal and tidal dykes/channels. Recorded in Rockland Broad 1903 R. Gurney. Abundant in Surlingham Broad June 12th 1903. R.Gurney Surlingham Broad October 1920 common.

Alona quadrangularis O.F.Müller. Collected in Wheatfen Broad August 1994 and from amongst sweet flag in Deep Waters September 1997. Recorded by R.Gurney from Rockland Broad 1903.

Alona rectangula Sars. Thatch Pond, Ingolds Dyke. Rare. August 1994. Recorded by R.Gurney from Rockland Broad 1903.

Pleuroxus aduncus Jurine. Osier Carr Pond, Home Dyke, August 1994. Osier Carr Pond receives flood waters directly from the tidal Home Dyke. Recorded by R.Gurney Rockland Broad and Surlingham Broad 1903.

Pleuroxus denticulatus Birge. A single specimen collected from the Boundary Dyke in August 1994. Not previously recorded locally. Confirmed from specimens in the adjacent Smee Loke Dyke in July 1995.

Pleuroxus trigonellus O.F.Müller. Ingolds Dyke, August 1994. Not recorded by R.Gurney from Yare Broads in 1904; R.Gurney October 1920 in Surlingham Broad as being common.

Pleuroxus uncinatus Baird. Specimens collected amongst water lilies in Fen Channel May 1999. Previously recorded from Rockland and Surlingham Broads by R.Gurney 1903.

Eurycercus lamellatus Müller. Specimens recorded from *Glyceria* hovers in the Bays. July 1994. Smee Loke Dyke July 1995. Deep Waters in algal mats July 4th 1997 where it was classified as being frequent. Recorded by R.Gurney from Surlingham and Rockland Broads 1903.

Graptoleberis testudinaria Fischer. Occasional amongst Fen Channel water lilies. July 1994. Recorded from Surlingham and Rockland Broads June 1903. R. Gurney.

Family Polyphemidae.

Polyphemus pediculus (L.). Smee Loke Dyke July 1995. Deep Waters amongst sweet flag *Acorus calamus* L. 26th September 1997 - occasional to frequent. There has been a loss of sweet flag in Deep Waters and elsewhere in Rockland Broad in the least two years which may affect the density and distribution of *Polyphemus pediculus*. Recorded from Surlingham and Rockland Broads R. Gurney 1904.

Table 1. Cladocera recorded in the mid-Yare river valley in the 20th C.

	Rockland	Surlingham	Wheatfen
Sida crystallina	1903	1903	1994-97
Diaphanosoma brachyurum		1903	
Daphnia pulex			1995-8
Daphnia hyalina var. *lacustris*			1994
Daphnia longispina	1903	1903	1994-99
Daphnia cucullata			1994
Daphnia obscura			1995
Simocephalus vetulus	1903	1902/20/21	1994-99
Simocephalus exspinosus			1997
Ceriodaphnia pulchella	1903	1903	1994-97
Ceriodaphnia reticulata	1903		
Scapholebris mucronata	1903	1903	1994-98
Bosmina longirostris	1903		1994-97
Macrothrix laticornis			1994
Eurycercus lamellatus	1903	1903	1994-98
Graptoleberis testudinaria	1903	1903	1994
Chydorus sphaericus	1903	1903/20	1994-99
Acroperus harpae	1903	1903	
Alona quadrangularis	1903	1903	1994-97
Alona rectangula	1903		1994-98
Alona affinis	1903		
Rhynchotalona rostrata	1903		
Pleuroxus denticulatus			1994-98
Pleuroxus trigonellus	1903	1903/20	1994-98
Pleuroxus aduncus	1903	1903	1994
Pleuroxus unciatus	1903	1903	1999
Polyphemus pediculus	1903	1903	1995-98
Total	**19**	**15**	**22**

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ROTIFERS: WHEATFEN BROAD

Norfolk & Norwich Naturalists' Society Microscopy Group
Research Committee Report

In May 1997 the Microscopy Group held a one day workshop led by Dr A.P.Saunders-Davies with the aim of examining the Rotifer populations of Wheatfen. There appears to be no records for Rotifers at Wheatfen so comparisons with the past and changes in the distribution of species cannot be made. However, it was felt to be of interest to survey the present fauna and to monitor changes over the next few years. Water quality is rapidly improving in the River Yare so one can expect that this will reflect changing rotifer communities and populations. Seventeen species were noted.

Class Rotifer
Family Brachionidae
Notholca labis Gosse. Smee Loke Dyke March 1997 K.B.Clarke. (Recorded by H.E.Hurrell 1902 at Southtown, Cobholm and Caister and by R.Freeman 1905 at Barton Broad)

Brachionus quadridentata (Herm.). Osier Carr Pond, Smee Loke Dyke, May 1997, A.P.Saunders-Davies.

Brachionus urceolaris Müller. Osier Carr Pond, Smee Loke Dyke, May 1997, A.P.Saunders-Davies. (Recorded by Hurrell 1903 Ormesby Broad; Freeman 1905 Sutton & Barton Broads).

Colurella colurus Ehr. Osier Carr Pond, Smee Loke Dyke, May 1997, A.P. Saunders-Davies.

Colurella oblonga Donn.. Osier Carr Pond, Smee Loke Dyke, May 1997, A.P. Saunders-Davies.

Lepadella ovalis. Müller. Osier Carr Pond, Smee Loke Dyke, May 1997, A.P.Saunders-Davies.

Mytilina mucronata (Müller). Osier Carr Pond, Smee Loke Dyke, May 1997, A.P.Saunders-Davies.

Mytilina ventralis Her. Osier Carr Pond, Smee Loke Dyke, May 1997, A.P.Saunders-Davies.

Family Notommatidae
Cephalodella gibba (Her.) Osier Carr Pond, May 1997, A.P. Saunders -Davies.

Cephalodella ventripes (D&N) Osier Carr Pond, Smee Loke Dyke, May 1997, A.P.Saunders-Davies.

Dipleuchlanis sp. Smee Loke Dyke 15.3.1997, K.B.Clarke.

Family Trichocercidae
Trichocera bicristata (Gosse). Osier Carr Pond, Smee Loke Dyke, May 1997, A.P.Saunders-Davies.

Trichocera porcellus (Gosse). Osier Carr Pond, Smee Loke Dyke, May 1997, A.P.Saunders-Davies.

Family Testudinellidae
Testudinella patina (Hermann). Osier Carr Pond, Smee Loke Dyke, May 1997, A.P.Saunders-Davies.

Family Flosculariidae
Ptygura sp. Osier Carr Pond, Smee Loke Dyke, May 1997. Saunders-Davies.

Family Philoninidae
Philodina citrina Ehr. Osier Carr Pond, Smee Loke Dyke, May 1997, A.P.Saunders-Davies. (Recorded by H.E.Hurrell 1902 in ditches at Caister).

Rotaria rotatoria (Pallas). Osier Carr Pond, Smee Loke Dyke, May 1997, A.P.Saunders-Davies.

Family Lecanidae
Lecane sp. Osier Carr Pond, Smee Loke Dyke, May 1997, A.P. Saunders-Davies.

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THE HOVERFLIES OF WHEATFEN AND ROCKLAND BROADS

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This review collates the records for both Wheatfen and Rockland Broads during the 20th century. The Wheatfen records are supplied by the Ted Ellis Trust and reflect the collections of nine observers since the mid-1930's. The species total for Wheatfen stands at 71 recordings. The recording for Rockland Broad by the author began in May 1992 using the public footpath from the staithe around the south of the broad to the River Yare. A total of 61 species has been recorded.

The species total for both sites is 83 from 39 genera. The dates given for Wheatfen are the earliest and most recent, whilst for Rockland they are the earliest

Species notes:
(1). *Asnasimyia interpuncta* (Harris) (Red Data Book Category 3) was collected by sweeping the *Glyceria maxima* beds in various parts of the fen by Dr Alan Stubbs. He wrote that, " This is a hoverfly which I placed on the

British list in 1981. You clearly have a strong population at Wheatfen. It is associated with *Glyceria maxima* (larvae semi-aquatic rat-tailed maggots), with Wheatfen one of the major Broadland sites for stands of this plant. The only other place I have found the hoverfly was at Bramerton, although there are some other Norfolk records. It is surprising that previous records for Wheatfen are lacking but it is an unobtrusive (though moderately large) species. It is just possible that the old *Lejops* record was for this species, though most misidentifications stand under *Helophilus lunulatus*". There is a single record from Rockland Broad when three females were noted on 29th June 1997 on hogweed flowers. *Glyceria maxima* is much reduced at Rockland Broad in recent years.

(2) *Cheilosia albitarsis* (Meigen) "breeds in roots of creeping buttercup". (Alan Stubbs).

(3) *Criorhina berberina* (Fab.) "Surlingham Wood, breeds in tree roots". (Alan Stubbs).

(4) *Episyrphus balteatus* (De Geer) " Swarms on honeysuckle". (E.A.Ellis): On *Angelica* flowers". (K.C.Durrant).

(5) *Eristalis arbustorum* L. "Laying eggs in mud in site cleared of sallow carr on Island, Wheatfen, 15.8.1997". (K.C.Durrant).

(6) In July 1997 approximately 700 rat-tailed maggot larvae were found in water which had collected in wheel ruts left by machinery near Rockland Broad. Some of these were reared and found to be *Eristalis interruptus* (Poda) A female was seen laying eggs in the mud around the wheel ruts.

(7) *Helophilus hybridus* Loew. A species looked for but not found at Rockland until 1997 when it became abundant.

Larvae of *Helophilus pendulus* were collected from blanket weed in a small pond at Hellington in July 1997.

(8) *Lejops vittata* (Meigen) (Red Date Book Category 2). Alan Stubbs notes that, "This is a hoverfly strongly associated with sea club rush, mainly found

on coastal grazing marshes".

(9) *Leucozona laternaria* (Müller). Ted Ellis wrote in 1950, "Apparently a new species to Britain. See C.Morley & E.A.Atmore, 1915 Diptera of Norfolk and Suffolk. *Trans. Norfolk Norwich Nats. Soc Supplement* 1-80. 'A few specimens on *Heracleum* flowers at Kings' Lynn".

(10) *Neoascia meticulosa* (Scop.). Large numbers swarming on vegetation near Rockland Broad, May 1996.

(11) *Syrphus ribesii* (L.) "Abundant on meadowsweet at Wheatfen - taking pollen, 14.8.1954" (E.A.Ellis).

Table 1. SYRPHIDAE (Hoverflies) of Wheatfen and Rockland Broads

	Wheatfen	**Rockland**
Anasimyia contracta Claussen & Torp	1997	1992
Anasimyia interpuncta (Harris)	1990-96	1997
Anasimyia lunulata (Meigen)	1986	
Anasimyia transfuga (L.)	1986	1999
Baccha elongata (Fab.)		1992
Brachyopa scutellaris Robineau-Desvoidy	1936	
Cheilosia *albitarsis* (Meigen)	1996	1996
Cheilosia illustrata (Harris)	1997	1992
Cheilosia impressa Loew	1993	
Cheilosia pagana (Meigen)	1986-93	
Cheilosia proxima (Zett.)	1939-93	
Cheilosia variabilis (Panzer)	1938-39	1997
Cheilosia vernalis (Fallén)	1992	
Chrysogaster cemiteriorum (L.)	1938-86	
Chrysogaster solstitialis (Fallén)	1989-93	1998
Chrysotoxum bicinctum (L.)	1936	1997
Chrysotoxum festivum (L.)	1997	
Chrysotoxum verralli Collin	1996	
Criorhina berberina (Fab.)	1996	
Epistrophe eligans (Harris)	1937-39	1995
Epistrophe grossulariae (Meigen)	1997	
Epistrophe nitidicollis (Meigen)	1997	
Episyrphus balteatus (De Geer)	1936-96	1992

Eristalinus sepulchralis (L.)	1936-97	1992
Eristalis arbustorum (L.)	1936-98	1992
Eristalis horticola (De Geer)	1936-97	1992
Eristalis interruptus (Poda)	1997	1992
Eristalis intricarius (L.)	1936-97	1992
Eristalis pertinax (Scop.)	1936-98	1992
Eristalis tenax (L.) Drone-fly	1936-98	1992
Eupeodes corollae (Fab.)	1936-39	1995
Eupeodes latifasciatus (Macquart)	1936-38	1994
Eupeodes luniger (Mg.)	1971	1992
Ferdinandea cuprea (Scop.)	1937	
Ferdinandea ruficornis (Fab.)	1993	
Helophilus hybridus Loew	1937-97	1997
Helophilus pendulus (L.)	1936-98	1992
Helophilus trivittatus (Fab.)		1995
Lejogaster tarsata (Meigen)	1993	
Lejops vittatus (Meigen)	1938	
Leucozona laternaria (Müller)	1938-87	
Leucozona lucorum (L.)	1938-96	1992
Melangyna labiatarum (Verrall)		1997
Melangyna umbellatarum (Fab.)	1939	
Melanogaster hirtella (Loew)	1938	1998
Melanostoma mellinum (L.)	1996	1992
Melanostoma scalare (Fab.)	1936-97	1997
Meligramma guttatum (Fallén)	1986	
Meliscaeva auricollis (Meigen)	1993	
Merodon equestris (Fab.)	1997	1997
Myathropa florea (L.)	1993-97	1992
Neoascia meticulosa (Scop.)	1986-87	1996
Neoascia podagrica (Fab.)	1937-39	
Neoascia tenur (Harris)	1993-97	
Parhelophilus frutetorum (Fab.)	1937-97	1995
Parhelophilus versicolor (Fab.)	1936-38	1995
Platycheirus albimanus (Fab.)	1993	1995
Platycheirus angustatus (Zett.)	1936-39	1997
Platycheirus clypeatus (Meigen)		1996
Platycheirus fulviventris (Macquart)	1997	1997
Platycheirus granditarsus (Forster)	1939-98	1994
Platycheirus peltatus (Mg).	1971	
Platycheirus rosarum (Fab.)	1986-97	1997

Episyrphus balteatus

Myathropa florea

Cheilosia illustrata

Chysotoxum verralli

Photographs by David Lester

THE ASIATIC CLAM *CORBICULA FLUMINEA* (Müller) NEW TO THE U.K.

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The Ted Ellis Trust: Wheatfen Broad, Surlingham NR14 7AL

Introduction

The Asiatic clam *Corbicula fluminea* (Müller) is a bivalve species of Eastern Asia: Philippines, China, Japan. It was reported in the Ohio River Basin USA in 1957 where it spread at a phenomenal rate over the whole drainage system. It is now widespread in both North and South America. In Europe it appeared in the late 1980's and it is now known from the Upper Rhine in Germany, the Lower Rhine in the Netherlands, Portugal, Spain and France.

The discovery by the authors of the clam in the River Chet in the southern Norfolk Broads in October 1998 is the first record from the U.K.

Taxonomy

Considerable confusion has occurred in the past over *Corbicula* taxonomy both in America and more recently in Europe. In America the studies of Britton and Morton (1979) concluded that all North American populations belonged to the single species *Corbicula fluminea*. Identification of *Corbicula fluminea* from the River Chet has been confirmed from comparisons with Dutch material from Drs Wm Backhuys and Drs A.D.P. Peursen of both *Corbicula fluminea* and *Corbicula fluminalis* (Müller) from the Lower Rhine. Dr Michael Kerney, Natural History Museum, London, has confirmed the identification. Specimens from the River Chet have been placed in the Natural History Museum.

River Chet

The River Chet is an enlarged stream dug out, widened and straightened in the late 1880's for wherry sailing traffic. It is really a canal from Loddon to the River Yare at Hardley Cross. Up until the late 1950's few boats used the Chet but in the early 1960's it was opened up for the growing holiday trade. The wash from pleasure boats has caused considerable erosion to the banks to the extent that for most of its length the R. Chet is encased in piling.There are few areas of natural ronded reed.

In 1940 the grazing marshes at Hardley were flooded and attempts to repair the banks failed. These marshes became reed dominated (*Phragmites australis*, *Glyceria maxima*, *Typha latifolia*) and today they form an extensive spillway (48ha) with shallow lagoons. The tidal range of the Chet is such that water flows into and ebbs out of the now named Hardley Flood. The bank separating Hardley Flood and the River Chet is low lying, narrow and reed dominated. At spring tides it is often under water. Hardley Flood is a haven for wildfowl and is currently used for wildfowling pursuits. There are large numbers of coot on the waters.

Chloride levels measured on the top of the tide on the Chet show that near the River Yare levels as high as 2170mg/l Cl^- occur whilst near the Hardley Flood the levels drop to between 220 and 460mg/l Cl . This range is very variable since comparable data collected one month later showed much lower levels of chloride. By collating both sets of data from the two high tides *Corbicula fluminea* is distributed in freshwaters between 44mg/l Cl^- and 460mg/l Cl^-. It appears that the clams can tolerate some exposure to low levels of salt water.

Corbicula fluminea is restricted to a 3km length of the River Chet above the normal saline intrusion zone. It is found in depths of 1-2m in silty-sands beyond the reed margins of the river. All European localities demonstrate that the species lives in substrata of sand, mud or gravel and many habitats are lotic receiving tidal influences. We inadvertently left one specimen caught in our nets which remained out of water for ten days. It was alive.

There is no evidence of its presence (winter 1998) at either Cantley Sugar Factory on the River Yare or at the inlet for the Suffolk & Essex Water Company at Belaugh on the Upper River Bure. Its presence at either of these two sites would be of considerable industrial signifiance. At Belaugh the Company extracts about 27,000m^3/day of water from the river through a 600mm pipe. The velocity down the pipe is 1.1m/sec. This is such a low velocity that the Asiatic clams would be able to colonise the bed of the pipe and so build up a major blockage of the inlet. Its presence in the inlet pipe would thus cause serious problems.

Population Data

In a sample collected on the 27th November 1998 the size-frequency analysis

indicated that there are four age groups living in the River Chet. The smallest represents a very recent hatching in possibly late October-early November. The maximum sized clam noted was 32mm in length.

Sinclair and Isom (1963) report that in the Tennessee River clams reach maturity during their first year at a length of 6.5mm but other data suggests that a size of 10.3 to 17.5mm is the norm. There is a free swimming planktonic veliger which feeds on phytoplankton. Although the veligers become part of the plankton, they are not true plankton creatures since the velum functions in ciliary feeding. During the benthic veliger stage the larvae drop out of the plankton and take up a bottom life where they grow a highly developed foot. This foot has cilia which helps it to anchor and retract to make rapid movements forward.

The evidence indicates that the Asiatic clam has been resident in the River Chet for upwards of four years. This conclusion is very tentative since we have no evidence as to whether the clam has an annual reproductive cycle or whether it breeds twice or three times a year in these northern waters. Since no dead shells were noted in the current survey the implication is that the largest clams have yet to reach their expected life span which in the USA is reported to be 7 years (Ingram, 1959).

The densities recorded during this survey can only be described as being broadly quantitative but the evidence, even though it is far from being conclusive, suggests that the population is expanding very rapidly in the River Chet from its earliest introduction and that in the coming years the numbers of Asiatic clams within the river will increase dramatically.

Discussion

The spread of *Corbicula fulminea* across continents has proved to be rapid. We are faced with three alternative strategies to repel this invasion.

Quarantine. Currently we can only make inspired guesses as to the origin of the River Chet population. Some European workers consider that the Asiatic clam has arrived in freshwater ballast from ships trading between European and Far Eastern ports. Certainly the early colonized sites are on major trading rivers leading to coastal harbours.We are more inclined to look at the aquaria

trade between Singapore, Hong Kong and Japan. Koi carp are regularly transported in water filled containers from these countries to the U.K. One Norfolk supplier flies out every two months to purchase new fish for the local market. However, he is of the considered opinion that the introductions arise more from the importation of aquatic plants for the aquarium trade than of fish. He cites the large aquatic plant farms of Singapore as one possible source. To quarantine either freshwater ballast or the tropical aquaria trade is in our view impractical.

The problem is not only of quarantine across continents as one of quarantine within the European continent. We have to face the fact that the Asiatic clam is now in Europe and spreading throughout the continent. We have evidence of how easy this can be from our own work in the River Chet when we noticed small clams in the silts clinging to the mud-anchor. Yachts and boats move freely across the North Sea from the Netherlands and we are totally incapable of preventing clams being transported attached to hulls or as in our case on the anchors.

In Broadland we are faced with another problem if we attempt control through quarantine. The shallow broads and rivers require regular dredging and removal of silts etc. Many of these are placed directly on the river banks but in other cases the spoil is transported throughout the system by barges to landfill sites. It will be impossible to prevent small clams being washed into new sites during these dredging programmes. Currently the Asiatic clam is confined to the River Chet but before any work is undertaken careful consideration to a number of questions will be necessary. Will spoil be placed on the river banks? How will the dredging barges, dredgers etc be cleaned before they are moved to other sites?

We are also faced with the possibility that the Asiatic clam will be spread through wildfowl. The nearby Hardley Flood is home to large numbers of duck, geese and coots. 4.6% of the food of coots includes mussels and other gastropods. Since the clam is present in small numbers inthe shallow waters of the Flood, then the spread throughout Broadland by birds is a distinct possibility in the coming years.

In the USA the Asiatic clam is food for many fish, including carp. Tench and

bream live in the River Chet and but we have little knowledge of their movements throughout Broadland.

2. Eradication. This is a distinct possibility for a short term U.K. solution. The Asiatic clam is restricted to a small section of a small river in Norfolk. Some form of molluscicide could be administered to kill off the population in its only known U.K. bridgehead. We recognise the practical problems associated with this undertaking, not least the potential outcry from environmentalists. Questions such as, "What is the differential effect of a molluscicide upon a mixed population of different species of snails and mussels? What is the rate of recovery of the different species after treatment by the molluscicide? Will any molluscicide guarantee total eradication? What are the wider effects since the River Chet is a tidal river and the molluscicide would be carried into other parts of the system? What are the rentention levels of the molluscicide in the river? "

We are, however, of the considered opinion that the spread of the Asiatic clam throughout the U.K. is inevitable and that eradication is not a serious option. Quarantine and massive campaigns of eradication are ways of buying time but since it will take only a few individual specimens to re-establish colonies in the U.K. we can only question their value. They are of course very costly but this will need to be weighed against the costs of control measures.

3. Control. In our opinion permanent control measures offer the best option. This involves careful monitoring of the known population, surveying of any spread from this site, monitoring of other potential sites throughout the U.K. inland waterways system, industrial control measures where water is extracted from rivers, lakes etc. *Corbicula fluminea* has recently been found in the River Waveney around Oulton Dyke (S.Müller, Cambridge University, February 1999) and in the River Yare at Strumpshaw (Environment Agency, May 1999). In both sites the numbers are small and are thought to represent clams which are up to two years old. In July 1999 clams were trawled from the Fleet Dyke in Rockland Broad and from the River Yare bordering Rockland Island. The lengths of the clams indicate that they are up to two years old in both these sites. The numbers are small and are in no way comparable to those found in the River Chet.

Within the Broads river system there are three abstraction points for public

water supply which may be affected, the two belonging to Essex and Suffolk Water are at the head of the tidal reaches at Belaugh on the Bure (10 million m^3 a year) and at Shipmeadow on the Waveney (9.95 million m^3 a year). The abstraction points of Anglian Water at Norwich are above the weir limiting tidal movement on the River Yare at Heigham and Costessey (17 million cubic metres a year). In addition 3.8 million m^3 a year are taken from the Yare for industrial purposes, mostly by Cantley Sugar Beet processing plant. We note that spray irrigation systems may be at risk from clams. 5.1 million m^3 of irrigation water is licensed from the River Yare catchment alone with a further 5 million m^3 for general agricultural use.

In the catchment of the Ely Ouse there is abstraction by Anglian Water at Stoke Ferry, British Sugar at Wissey and the massive works of the Ely Ouse-Essex Transfer scheme at Black Dyke on the Cut-off Channel. All these are at potential risk from clam growth.

One of us (KBC) was involved with the difficulties caused by *Corbicula* in the catchment of the Ohio River in the 1950's and in advising on control methods. The difficulties there included the blocking of pumps and intakes to waterworks and the blocking of condenser tubing on steam and refridgeration plants. Accumulation of shells caused difficulties in sedimentation facilities. In sand and gravel extraction plants the clams could not be removed by screening and went forward to be mixed in concrete with subsequent loss of strength and fouling of the concrete.

A threat which has not been investigated is the blockage of spray irrigation nozzles by young clams in their first year.

Cleaning of the Ely Ouse-Essex Transfer tunnel, at present being undertaken is relatively simple, involving the removal and dumping of a relatively innocuous mud consisting largely of decomposed diatoms and plant remains. If, however, *Corbicula* was present the material would not only be more difficult to remove from the 13km of tunnel but also the presence of the rotting flesh would present a major disposal problem.

Permanent control also necessitates careful monitoring of the ecology of the population(s). We know from other invasive species that in time control may

occur through natural agencies such as competition, predation etc. Sinclair and

Isom (1963) observe that one of the predators is the flatworm *Dugesia tigrina* (Girard) which feeds on the clam flesh. This is a North American species which has been introduced into the U.K.via the trade in ornamental fish for aquaria. We have collected specimens at nearby Wheatfen Broad so it is likely that it also exists in the Chet and/or Hardley Flood. Ecological balance may be achieved. Surveys in Europe suggest that other native species may be affected by the Asiatic clam. Unionid mussels decline in numbers and *Pisidium amnicum* (Müller) is thought to be directly affected by the growth of the clam populations. *Pisidium amnicum* is a dominant species in the reaches of the River Chet above Hardley Flood.

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WILDLIFE 2000

VEGETATION AND LAND-USE SURVEY OF THE RONDS OF THE BROADS RIVERS.

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History of the Ronds

The terms 'rond' and 'rand' appear to be used interchangeably to describe the narrow strip of land between a river and its' embankments or by-passed broad. It is likely that the origin of the term lies in the Dutch word 'rand' meaning edge or brink, and may reflect the Dutch influence on land drainage in East Anglia. In The Broads, 'rond' is the local derivation of 'rand', and is applied in a more restricted sense to the shelf-like area between the river and its' floodbanks (Ellis, 1965). The local meaning is used in this paper.

George (1992), in his account of the history of marsh reclamation in *The Broads*, suggested that river embankment began in the late thirteenth and fourteenth centuries in response to the need for new agricultural land and possibly also to a rise in water levels in the rivers. The floodbank was set back from the river's edge, and was constructed from material excavated from the soke dyke on the landward side of it. Although the strength and durability of the floodbank would increase the greater its' distance from the river's edge, the primary function of the ronds was probably for flood alleviation by acting as 'mini-washlands' temporarily storing flood waters. This view is supported by the fact that the ronds are widest beside the lower, more tidal reaches of the Bure, Waveney and Yare.

The original extent of the ronds is uncertain. They may have extended further upstream than at present, having been lost over the years as a result of erosion and neglect of the floodbanks. It is also likely that ronds on opposite sides of the river were originally of equal width, and that the present uneven and fragmented pattern is due to meander migration accelerated over the last few decades by boat-wash from the increasing numbers of powered craft.

There is no detailed historical record of management of the ronds, but medieval uses would have included grazing by sheep and cattle where saltmarsh vegetation predominated, and the harvesting of reed for thatching further upstream. The water level on some ronds may also have been controlled for the production of marsh hay. During this century, the wide ronds on the lower reaches of all the rivers were cut for reed; upstream to Acle on the Bure, to Oulton Dyke on the Wavency, and to Hardley on the Yare. The practice gradually declined and, by the early 1980s, reed cutting was limited to only a few locations. Poor reed growth appears to be the main reason for a cessation in cutting, with the reed stems not attaining the 4 feet required for commercial reed. Where reed production was not paramount, cattle and sheep grazing the floodbank would have had free access to the rond provided there was no barrier dyke at the rear of the rond. This practice may also have declined over the years due to the risk of animals falling from the eroded, undercut ronds into the increasingly fast-flowing rivers.

Importance of the ronds

The ronds continue to be an integral part of flood protection in The Broads, forming the first line of defence by accommodating flood waters and reducing hydraulic pressure on the vulnerable floodbanks, and buffering them from erosion and scour. They are also a valuable feature of The Broads landscape, providing a fringe of attractive wetland vegetation between the river's edge and the floodbank. The ronds constitute part of the nationally important wetland resource of The Broads area, and are of special ecological interest since they provide a continuum of semi-natural vegetation which spans the gradient between marine and freshwater environments.

Extent of the ronds

The rivers Bure, Yare and Waveney are continuously embanked on both sides for about 31, 29 and 39km from the sea respectively, and the River Thurne for about 3km from its' confluence with the Bure. Ronds are present along these embanked stretches, but their width and continuity varies as a result of riverbank erosion. This is most noticeable on the lower reaches where the rivers now meander between floodbanks as a result of erosion on the outside of bends. Erosion is most marked on the Bure and Wavency where the rond has completely disappeared on several bends, necessitating protection of the flood bank by piling. Extensive, wide ronds remain on the Bure up to Acle

Bridge, on the Yare up to the Beauchamp Arms and on the Waveney to one kilometre downstream of Beccles. Upstream of these points, the main rivers and their tributaries the Thurne, Chet and Ant have only short, narrow fragments of ronds, and these were not included in this study. Total lengths and areas of rond are shown in Table 1.

Rond feature	Yare	Waveney	Bure	Thurne
Total rond length (km) [ϕ]	28.3	46.6	25.6	5.0
Total rond area (ha) [ϕ]	68.4	170.4	70.2	6.5
Rond length with reed cutting * (km)	4.4	9.2	2.4	0
Rond area with reed cutting (ha)	10.9	58.3	8.1	0
Rond length grazed by stock (km)	0.8	4.3	5.9	0
Rond area grazed by stock (ha)	3.5	12.7	16.9	0
Rond length with spoil deposition [†] (km)	0.3	3.0	3.5	1.4
Rond length heavily grazed by feral geese (km)	1.3	0	0	0
Rond length used by anglers [#] (km)	2.0	2.0	1.1	0
Length of unmanaged rond (km)	20.9	29.1	12.8	3.6

[ϕ] = total for left and right banks
* = lengths and areas are for reedbed cut regularly or occasionally between 1988 and 1992
[†] = spoil deposited on the rond between 1987 and 1992
[#] = angling activity with and without platforms

Table 1. Land use and management of ronds

Management of the ronds

The majority of the ronds are unmanaged; the percentage length of unmanaged ronds in 1992 was 74, 63 and 72% for the Yare, Waveney and Bure respectively (Table 1). Reed cutting and grazing were the most frequent land use. The current pattern is for selective reed cutting on the Waveney ronds bordering Haddiscoe Island in years when reed growth is vigorous, and for more regular cutting in the middle reaches of the Bure and Yare at Stokesby and Reedham respectively. Grazing by sheep and cattle continues to the present day on ronds between Oulton Dyke and St. Olaves on the Waveney, and at Stokesby, Runham and Mautby on the Bure.

Spoil was commonly deposited on the ronds during river dredging operations,

and continuous lengths of up to 1.5km have been used for this practice on the Waveney. Angling is generally limited to the upstream reaches of the rivers, and concentrated in areas where fishing rights are held by angling clubs. The rond vegetation may be trampled or cut around fishing platforms at these locations. There is also localised grazing of the ronds by feral geese, and this was most noticeable near the Beauchamp Arms public house on the Yare.

Hydrology

The hydrological regimes operating on the ronds are a major factor affecting the vegetation. The lengths of rivers with ronds present are all subject to tidal influence (George 1992). Tidal action and fluvial flows determine the water levels in the rivers, and thus the extent and duration of inundation of the ronds and the salinity of the flood waters. On a local scale, the topography and drainage of individual ronds also influences the plant communities.

The salinity in the rivers decreases with distance from the sea. Between October 1991 and September 1992, ronds on the River Bure at distances of 10 and 23 kilometres inland were inundated with water of mean salinities 16.8 and 1.8 g/l Cl^- respectively. On the River Waveney, ronds at 12, 19 and 29km inland were flooded with water of mean salinities 9.6, 2.3 and 0.31 g/l Cl^- respectively (salinity data from Environment Agency). The number of inundations of the ronds also decreases from the downstream to upstream reaches. Mean high water levels at Gorleston are 0.9m for spring tides and 0.6 metres for neap tides. The mean height of the downstream ronds is 0.9m above Ordnance Datum (Newlyn), and they are inundated regularly on spring tides, thus experiencing a regime that borders between upper and lower saltmarsh. Tidal height data (Environment Agency) indicates that ronds over 20 kilometres inland are flooded much less frequently, between 30 and 50 times annually. However, rond height varies by as much as 0.7m above Ordnance Datum (unpublished topographical surveys 1983 Richard Youngs) and this accounts for local interruptions in the gradation of vegetation from swamp to drier fen communities.

Rond profiles show a typical pattern, with a negative gradient from the rond edge to floodbank. This often results in incomplete drainage of flood waters from the low-lying areas at the rear of the rond, and areas poached by

cattle. It is also likely that a dyke was originally constructed at the base of the floodbank, which has gradually silted up in many locations forming shallow pools. A raised 'lip' at the rond edge is also a common feature which further impedes drainage. Although this has been caused by the deposition of river dredgings on some ronds, sediment accretion from river water may have occurred where there is fringing reed.

Drainage channels, known locally as foot drains, are present on most of the downstream ronds. Although there is little evidence of recent maintenance and many are overgrown and silted up, these channels remain the major route by which water enters and leaves the ronds. In many cases, inundation occurs from the rear of the rond via overtopping of the foot drains as the tide rises. Where drainage is impeded by the factors described above, a cycle of inundation, incomplete drainage and evaporation can result in the rond surface becoming more saline than the river water. Comparison of electrical conductivites of river and standing water on the ronds in 1992, showed this to be the case on the downstream ronds during a run of drought years. Natural flushing of the ronds by freshwater in years where there is adequate rainfall will reverse this effect.

Vegetation survey method

Every length of rond was visited in 1992. An overall description of the vegetation was made, including any typical or unusual features and vegetation patterns. Distinct, homogeneous vegetation types were identified and 4m x 4m quadrats recorded using the National Vegetation Classification (NVC) methodology (Rodwell 1995). At least one quadrat was recorded for each stand on every rond. Quadrats were not located within 1m of the toe of the floodbank or the river edge to avoid transitional communities and species which were not typical of the main body of the rond. Ronds which are covered with dredgings, heavily shaded by trees / shrubs or narrow with piled edges were not sampled.

The vegetation data (205 quadrats) were divided into two distinct groups; saltmarsh vegetation and brackish to freshwater communities. TWINSPAN (Hill 1979) was then used to produce separate classifications for each. MATCH (Malloch 1992) was also used to compare the TWINSPAN end-groups to the NVC communities.

Vegetation of the ronds

The ronds support a variety of wetland vegetation types as a result of the range of environmental conditions and management. Saltmarsh, brackish and freshwater plant communities reflect the tidal influence and salinity along the length of each river, and are modified further by grazing and reed cutting. The vegetation has been classified into six broad categories: saltmarsh, unmanaged brackish reedswamp, managed reedswamp, depauperate reedswamp, non-reed swamp and fen. These are mapped in Figures 1, 2 and 3. Within these categories, the composition and structure of the vegetation is determined by the width, topography and hydrological regime of individual ronds, and results in a mosaic of plant communities.

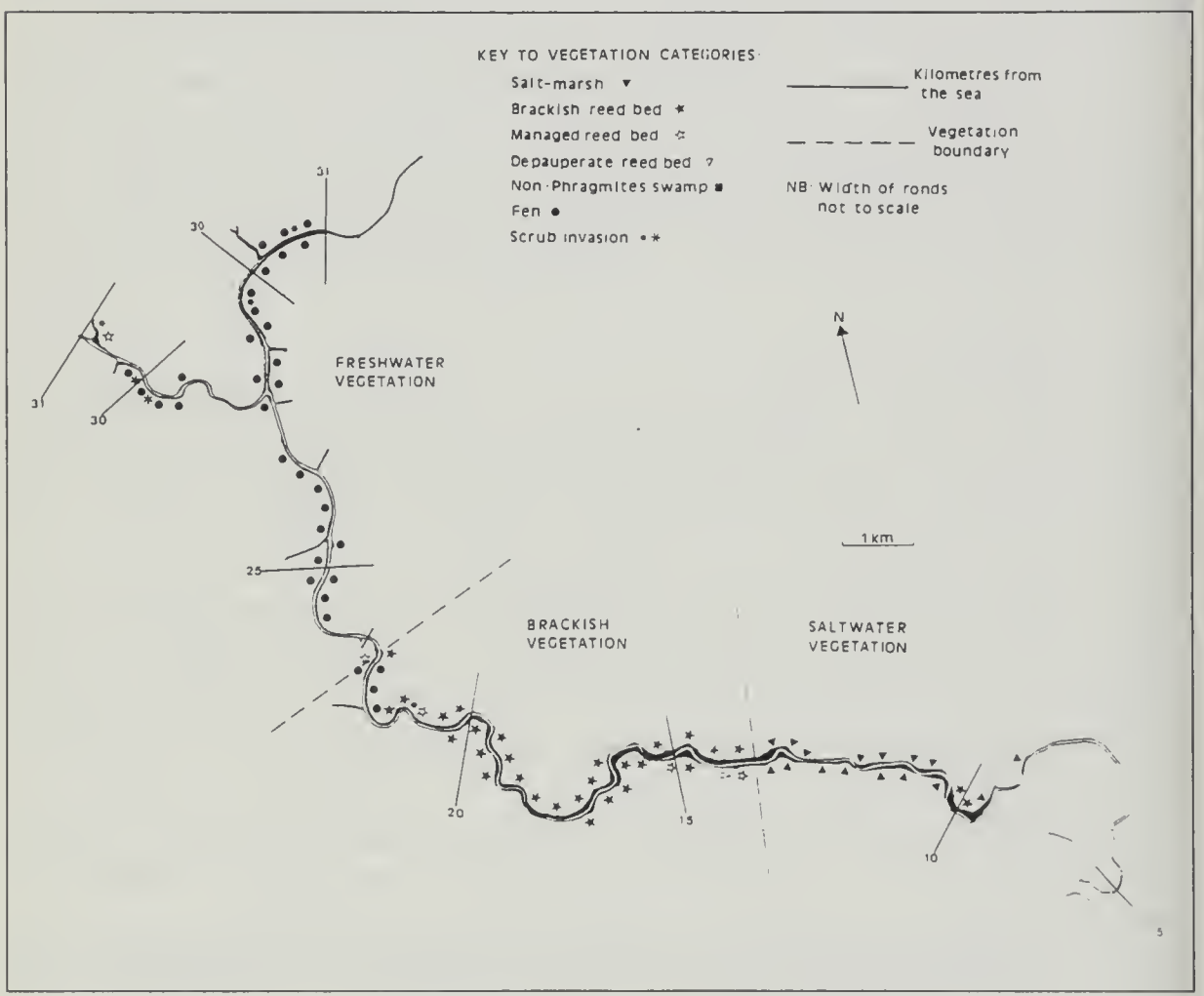


Figure 1. Vegetation map of the ronds of the Rivers Bure and Thurne

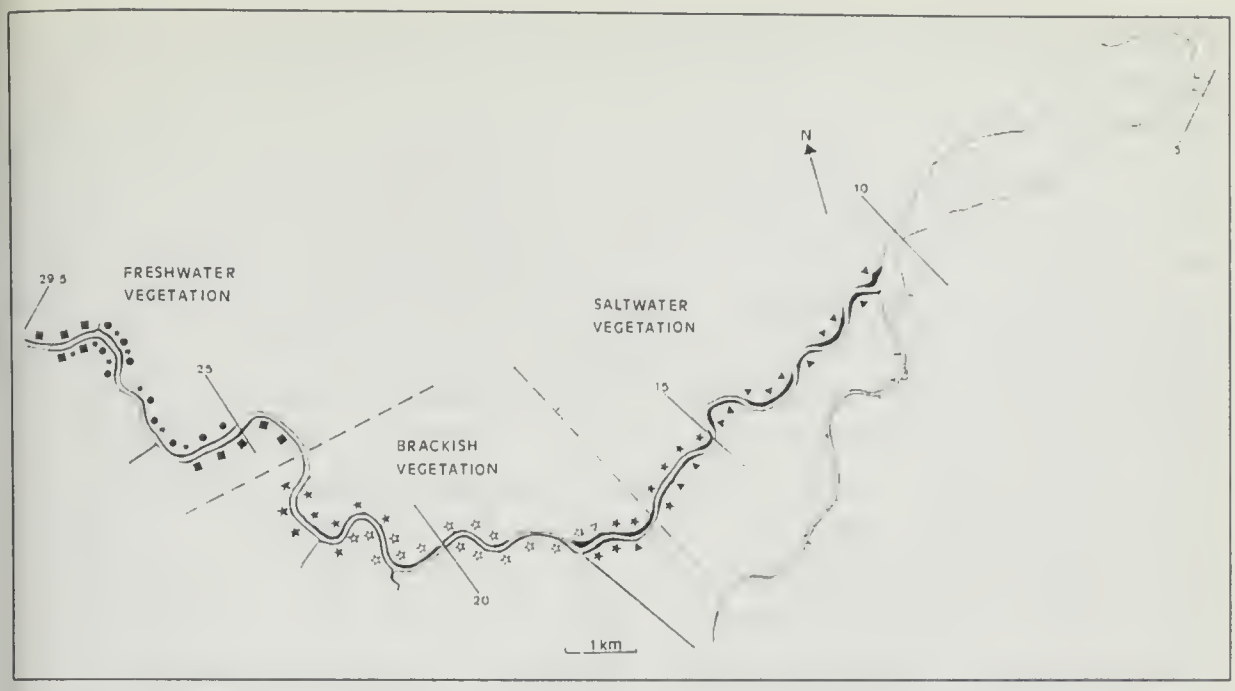


Figure 2. Vegetation map of the ronds of the River Yare

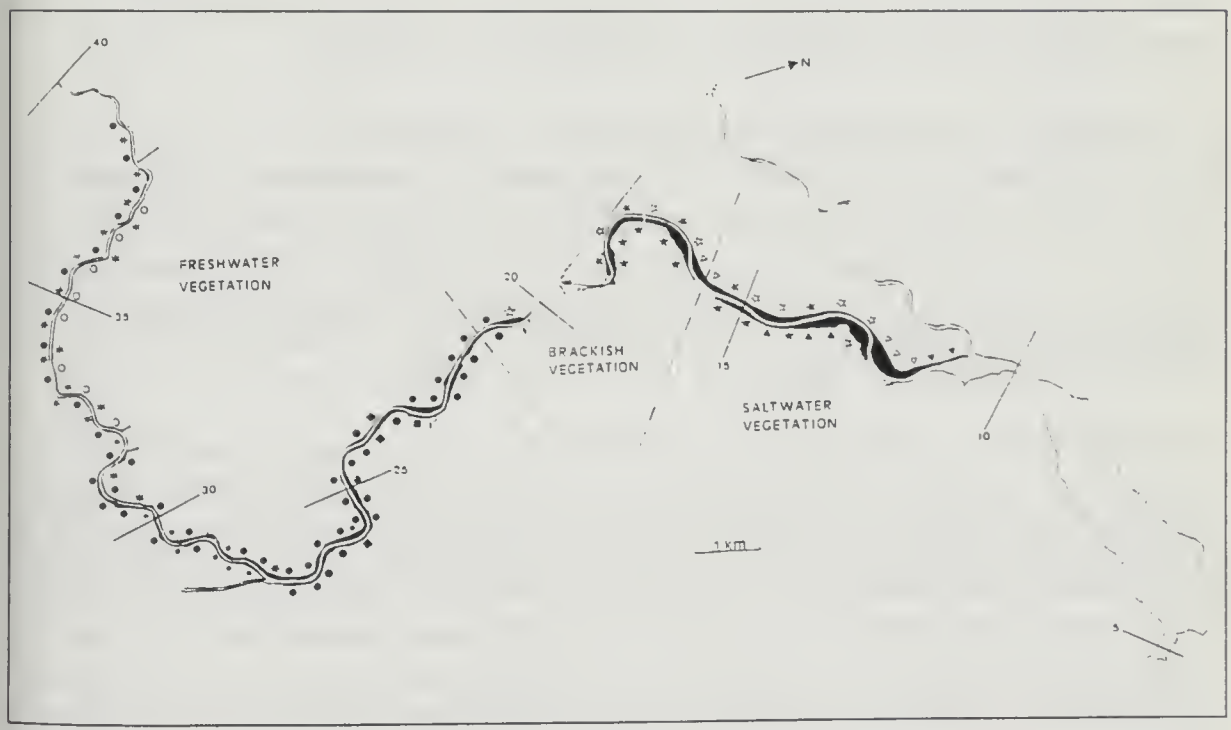


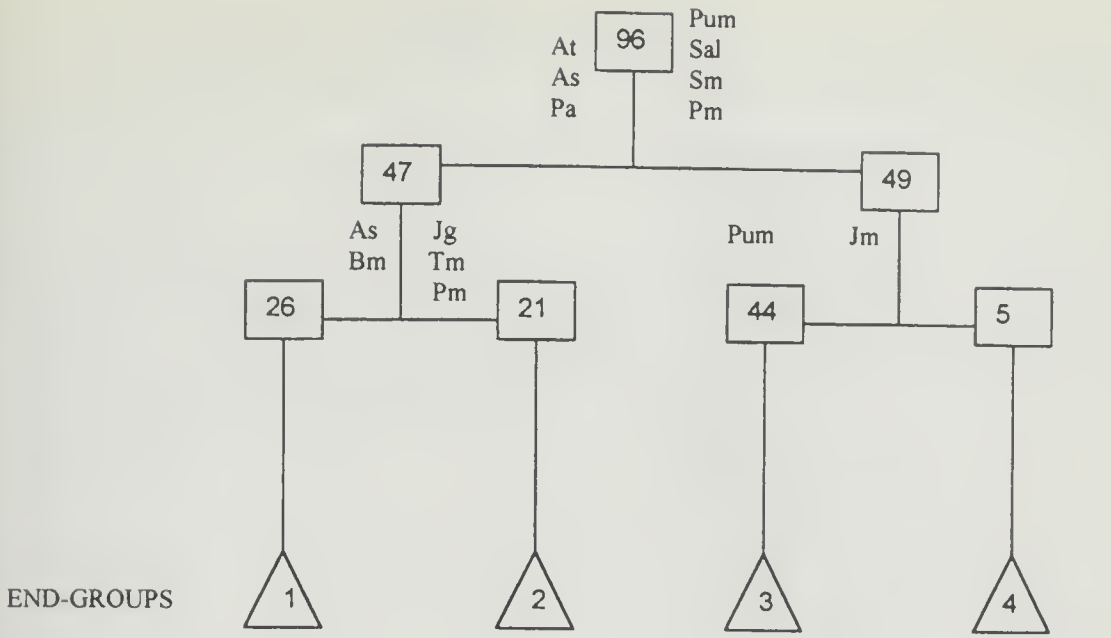
Figure 3. Vegetation map of the ronds of the River Waveney

There are a number of general features which are typical of the rond habitats and pattern of the vegetation. Permanent, shallow pools occur on wide ronds on the lower reaches of the rivers, and often support rafts of green algae *Enteromorpha* spp. in summer. These are most extensive in depressions at the back of the ronds close to the floodbank. Also in the lower reaches, common reed *Phragmites australis* is consistently taller adjacent to rond drainage channels and at the river's edge: in fact, the height of the reed is invariably indicative of the presence of foot drains. In the most saline reaches, the *Phragmites* reedswamp on the edges of these channels is replaced by fringes of mono-dominant sea couch *Elytrigia atherica*, which sometimes extend up to 10m into the rond. In contrast, the ronds on the upper reaches of the Waveney upstream of Burgh St. Peter are unusual in that they are colonized by numerous mature trees and shrubs including willows *Salix* spp., alder *Alnus glutinosa*, ash *Fraxinus excelsior*, hawthorn *Crataegus monogyna* and guelder rose *Viburnum opulus*. These are usually rooted at the base of the floodbank or at the river's edge, but in areas where spoil has been deposited, the whole width of the rond has been invaded by willows. Ronds shaded by trees and shrubs have a sparse understory of wetland vegetation comprising mainly pond sedges *Carex riparia* and *Carex acutiformis*, common reed *Phragmites australis*, reed canary grass *Phalaris arundinaceae* and nettle *Urtica dioica*.

TWINSPAN classification of the rond plant communities

The dendrograms of the TWINSPAN vegetation classifications are shown in Figures 4 & 5. Eleven end-groups were identified, and the constancy tables for the plant communities are given in Table 2. The distribution of the communities along the river system and rond management are also indicated on the dendrograms in Figures 4 & 5.

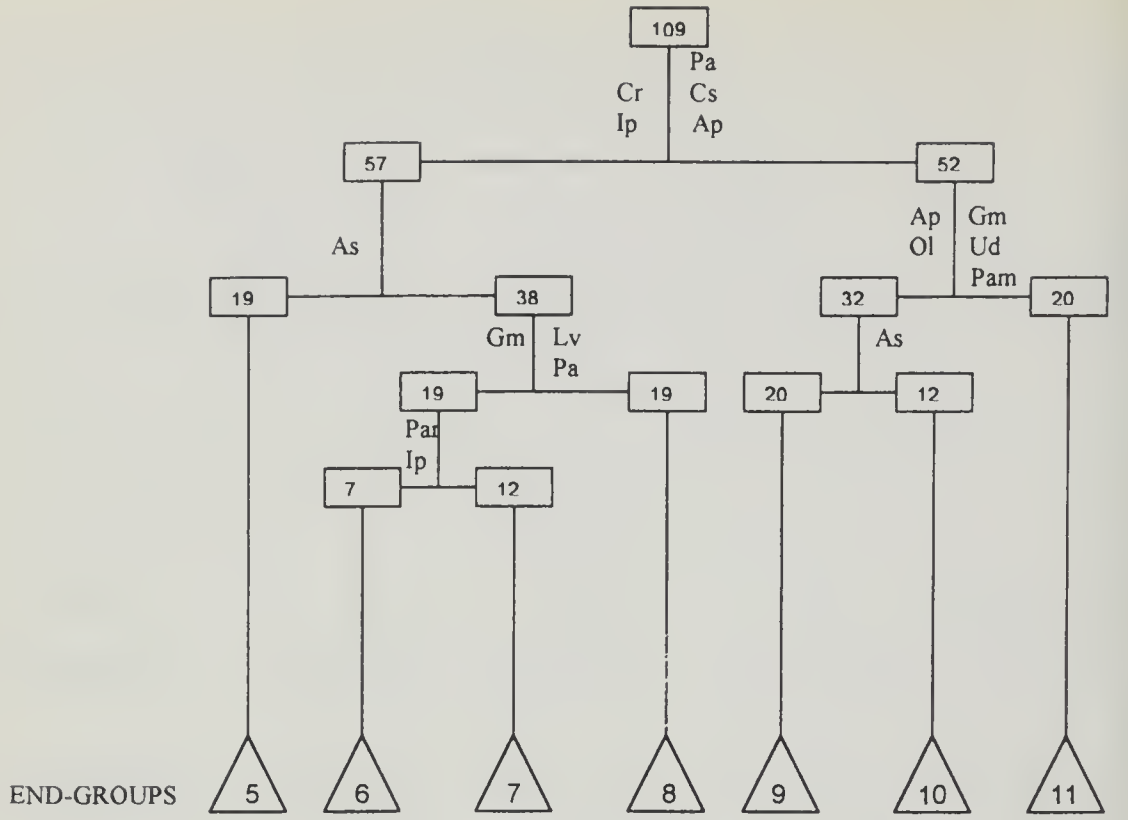
End-groups 1 to 4 encompass the range of vegetation occurring along the lower, most saline reaches of all three main rivers, to a distance of 23km upstream from the river mouth at Great Yarmouth. End-groups 1 and 2 are brackish reedswamp communities which typically occur in the wetter areas at the back of the ronds. They both have a range of halophytes in the understorey including abundant seedlings of sea aster *Aster tripolium*, but end-group 2 is characterised by the well-developed understorey of saltmarsh rush *Juncus gerardii* and depauperate reed which averages only about 1m in height. This community is typical of unmanaged reedswamp and abandoned commercial reedswamp on



Figures in boxes are the number of quadrats in each sub-division.
Right and left banks are when facing downstream, and the figures above the horizontal lines are the distances in kilometres from the sea at which the end-group community occurs.

Indicator species codes are:
Agrostis stolonifera (As), *Aster tripolium* (At), *Phragmites australis* (Pa), *Puccinellia maritima* (Pum, *Salicornia* spp. (Sal), *Spergularia media* (Sm), *Plantago maritima* (Pm), *Bolboschoenus maritimus* (Bm), *Juncus gerardii* (Jg), *Triglochin maritima* (Tm), *Juncus maritimus* (Jm), *Carex riparia* (Cr), *Iris pseudacorus* (Ip), *Calystegia sepium* (Cs), *Atriplex hastata* (Ah), *Oenanthe lachenalii* (Ol), *Glyceria maxima* (Gm), *Urtica dioica* (Ud), *Persicaria amphibia* (Pam), *Lysimachia vulgaris* (Lv), *Phalaris arundinaceae* (Par).

Figure 4. TWINSPAN classification of the saltmarsh vegetation



LAND USE		5	6	7	8	9	10	11
		+ or -	none	none	none	reed	past reed	none
		grazing				cutting	cutting	
WAVENEY	Right bank	20 to 27	20 to 27	22 to 38	24 to 38		22	36 to 38
	Left bank	22 to 24	22 to 24	24 to 38	29 to 30	16 to 21		
YARE	Right bank	24 to 30	24 to 30	28 to 29		17 to 21	21 to 22	
	Left bank	28 to 30	28 to 30	25 to 29	25 to 29	17 to 21	21 to 22	25 to 29
BURE	Right bank					19 to 20		24 to 31
	Left bank					21 & 31	20 to 23	24 to 27
THURNE	Right bank							30 to 31
	Left bank							28 to 29

See footnote of Figure 4 for explanation of dendrogam and indicator species codes.

Figure 5. TWINSPAN classification of the brackish and freshwater vegetation

Table 2. Constancy tables for the TWINSPAN end-groups.

End-group 1. Brackish reedswamp

Phragmites australis	V	3-9
Aster tripolium	V	1-8
Atriplex prostrata	V	I-4
Agrostis stolonifera	IV	2-7
Bolboschoenus maritimus	III	1-7
Juncus gerardii	III	3-6
Cochlearia officinalis	III	2-5
Glaux maritima	II	I-4
Triglochin maritima	II	I-4
Apium graveolens	I	4
Puccinellia maritima	I	2-9
Festuca rubra	I	3-4
Suaeda maritima	I	1-4
Enteromorpha spp.	I	2-3
Juncus maritimus	I	3
Calystegia sepium	I	2
Oenanthe lachenalii	I	I
Aster tripolium var. *discoideus*	I	1
Spergularia media	I	I
Number of samples	26	
Number of species / sample	7.4 (4-10)	

End-group 2. Depauperate reedswamp

Phragmites australis	V	2-9
Juncus gerardii	V	3-10
Aster tripolium	V	1-9
Glaux maritima	V	I-4
Cochlearia officinalis	III	2-7
Atriplex prostrata	III	I-5
Plantago maritima	III	I-3
Agrostis stolonifera	II	1-8
Elytrigia atherica	II	2-3
Bolboschoenus maritimus	I	1-4
Enteromorpha spp.	I	3
Salicornia agg.	I	2-3
Suaeda maritima	I	3
Apium graveolens	I	I-3
Spergularia media	I	I-3
Oenanthe lachenalii	I	1
Juncus maritimus	I	I
Puccinellia maritima	I	1
Atriplex portulacoides	I	1
Number of samples	21	
Number of species / sample	7.2 (5-11)	

End-group 3. Low turf saltmarsh

Puccinellia maritima	V	2-9
Plantago maritima	V	1-8
Aster tripolium	V	I-5
Spergularia media	V	I-4
Juncus gerardii	IV	3-9
Phragmites australis	IV	1-9
Triglochin maritima	IV	I-8
Salicornia agg.	III	I-6
Suaeda maritima	III	1-6
Atriplex prostrata	III	I-5
Cochlearia officinalis	III	I-4
Glaux maritima	III	I-4
Enteromorpha spp.	II	I-4
Bolboschoenus maritimus	I	2-6
Limonium vulgare	I	1-4
Atriplex littoralis	I	I-4
Juncus maritimus	I	2
Spergularia marina	I	I-2
Atriplex portulacoides	I	I
Number of samples	44	
Number of species / sample	9.1 (5-14)	

End-group 4. Sea rush stands

Juncus maritimus	V	8-10
Juncus gerardii	V	3-4
Cochlearia officinalis	V	2-3
Triglochin maritima	V	2
Atriplex prostrata	V	2
Phragmites australis	V	1-2
Puccinellia maritima	III	5
Plantago maritima	III	3
Bolboschoenus maritimus	III	2
Enteromorpha spp.	III	2
Limonium vulgare	III	2
Spergularia media	III	2
Salicornia agg.	III	2
Aster tripolium var. *discoideus*	III	2
Glaux maritima	I	I
Number of samples	5	
Number of species / sample	10.5 (9-12)	

Table 2. Constancy tables for the TWINSPAN end-groups

End-group 5. *Agrostis stolonifera* swamp

Agrostis stolonifera	V	2-9
Carex riparia	V	2-9
Galium palustre	IV	1-5
Mentha aquatica	IV	1-5
Rorippa nasturtium-aquaticum	IV	1-3
Phragmites australis	III	1-8
Glyceria maxima	III	1-7
Berula erecta	III	1-6
Iris pseudacorus	III	1-3
Myosotis laxa subsp. *caespitosa*	III	1-3
Caltha palustris	III	1-2
Rumex conglomeratus	III	1-2
Juncus subnodulosus	II	2-9
Schoenoplectus tabernaemontani	II	1-5
Oenanthe fistulosa	II	1-4
Ranunculus sceleratus	II	1-2
Rumex hydrolapathum	II	1-2
Epilobium hirsutum	II	1
Phalaris arundinaceae	I	3-9
Valeriana officinalis	I	4
Juncus inflexus	I	2-4
Typha latifolia	I	3
Lysimachis vulgaris	I	2-3
Samolus valerandii	I	1-3
Enteromorpha spp.	I	2
Ranunculus repens	I	2
Lycopus europaaeus	I	2
Filipendula ulmaria	I	2
Elytrigia atherica	I	2
Persicaria amphibia	I	2
Veronica beccabunga	I	1-2
Persicaria hydropiper	I	1
Persicaria laxiflora	I	1
Ranunculus bulbosus	I	1
Myosotis scorpioides	I	1
Eupatorium cannabinum	I	1
Calystegia sepium	I	1
Lythrum salicaria	I	1
Apium graveolens	I	1
Atriplex prostrata	I	1
Oenanthe lachenalii	I	I
Number of samples	19	
Number of species / sample	11 (15-18)	

End-group 6. Carex / Glyceria swamp.

Carex riparia	V	3-10
Gylceria maxima	V	2-9
Phalaris arundinaceae	V	2-6
Iris pseudacorus	V	2-4
Carex paniculata	III	3-4
Galium palustre	III	2-3
Mentha aquatica	III	2-3
Phragmites australis	III	2-3
Berula erecta	III	1-2
Myosotis scorpioides	III	1-2
Rumex conglomeratus	III	I
Lycopus europaeus	II	2-3
Veronica beccabunga	II	I-2
Epilobium hirsutum	II	I-2
Atriplex prostrata	II	1-2
Caltha palustris	II	I
Valeriana officinalis	II	I
Persicaria amphibia	II	1
Juncus inflexus	I	3
Senecio vulgaris	I	2
Sonchus asper	I	1-2
Rorippa nasturtium-aquaticum	I	1
Barbarea vulgaris	I	1
Filipendula ulmaria	1	1
Urtica dioica	1	1
Sonchus arvensis	1	1
Carex otrubae	I	1
Number of samples	7	
Number of species / sample	10.3 (8-17)	

End-group 7. *Glyceria maxima* fen

Glyceria maxima	V	9-10
Phragmites australis	II	1-3
Carex riparia	I	4
Solanum dulcamara	I	3
Agrostis stolonifera	1	3
Impatiens capensis	1	2
Iris pseudacorus	I	1
Lycopus europaeus	I	1
Number of samples	12	
Number of species / sample	3 (1-5)	

TABLE 2. Constancy tables for the TWINSPAN end-groups

End-group 8. Fen

Phragmites australis	V	3-9
Carex riparia	V	4-8
Phalaris arundinaceae	IV	2-6
Filipendula ulmaria	IV	1-4
Lysimachia vulgaris	IV	1-4
Iris pseudacorus	IV	1-4
Glyceria maxima	III	2-6
Epilobium hirsutum	II	1-8
Carex paniculata	II	4-5
Typha angustifolia	II	1-4
Rumex hydrolapathum	II	1-4
Thalictrum flavum	II	1-3
Calystegia sepium	II	1-3
Valeriana officinalis	II	1-2
Eupatorium cannabinum	I	4
Humulus lupulus	I	4
Persicaria amphibia	I	2
Solanum dulcamara	I	2
Urtica dioica	I	2
Typha latifolia	I	1-2
Equisetum arvense	I	1
Stachys palustris	I	1
Sonchus palustris	I	1
Lythrum salicaria	I	1
Number of samples	19	
Number of species / sample	8.2 (5-11)	

End-group 9. Managed reedswamp

Phragmites australis	V	4-10
Atriplex prostrata	V	1-6
Calystegia sepium	III	1-6
Carex riparia	III	1-4
Oenanthe lachenalii	III	1-4
Aster tripolium	III	1-4
Iris pseudacorus	II	1-3
Rumex crispus	II	1-2
Glyceria maxima	I	4-9
Phalaris arundinaceae	I	3-5
Bolboschoenus maritimus	I	3
Chenopodium bonus-henricus	I	3
Lythrum salicaria	I	1-3
Sonchus palustris	I	1-3
Persicaria amphibia	I	2
Apium graveolens	I	2
Sonchus arvensis	I	2
Agrostis stolonifera	I	2
Rumex hydrolapathum	I	1
Oenanthe fistulosa	I	1
Caltha palustris	I	1
Eupatorium cannabinum	I	1
Ranunculus sceleratus	I	1
Cirsium arvense	I	1
Number of samples	20	
Number of species / sample	6.5 (2-9)	

End-group 10. Abandoned commercial reedswamp.

Phragmites australis	V	2-9
Agrostis stolonifera	V	6-10
Atriplex prostrata	IV	2-5
Oenanthe lachenalii	IV	1-4
Calystegia sepium	III	2-5
Bolboschoenus maritimus	III	1-3
Lythrum salicaria	III	1-2
Cochlearia officinalis	II	1-4
Aster tripolium	II	3-5
Rumex crispus	II	1
Carex riparia	II	3
Rumex hydrolapathum	II	1
Elytrigia atherica	I	3
Iris pseudacorus	I	3
Phalaris arundinaceae	I	3

End-group 11. Fen

Phragmites australis	V	1-10
Calystegia sepium	V	1-7
Glyceria maxima	IV	2-9
Persicaria amphibia	IV	2-4
Carex riparia	III	2-6
Urtica dioica	III	1-4
Galium aparine	III	1-4
Phalaris arundinaceae	II	1-5
Solanum dulcamara	II	2-4
Sonchus palustris	II	1-4
Cirsium arvense	II	1-3
Eupatorium cannabinum	II	1-2
Humulus lupulus	I	1-4
Epilobium hirsutum	I	1-4
Elymus repens	I	3

Table 2. Constancy tables for the TWINSPAN end-groups

Galium palustre	I	3
Sonchus arvensis	1	1-2
Glaux maritima	1	1
Sonchus palustris	1	1
Althaea officinalis	I	1
Thalictrum flavum	1	1
Lysimachia vulgaris	1	1
Mentha aquatica	I	1
Solanum dulcamara	I	1
Elymus repens	1	1
Number of samples	12	
Number of species / sample	7.6 (4-13)	

Arrhenatherum elatius	1	2-3
Lythrum salicaria	I	1-3
Typha angustifolia	I	2
Iris pseudacorus	I	2
Thalictrum flavum	1	2
Scutellaria galericulata	I	2
Typha latifolia	I	1-2
Rumex hydrolapathum	I	1-2
Impatiens capensis	I	1-2
Atriplex prostrata	I	1-2
Mentha aquatica	1	1
Filipendula ulmaria	1	1
Stachys palustris	1	1
Angelica sylvestris	I	1
Picris echioides	I	1
Populus nigra (seedling)	1	1
Ribes nigrum	1	1
Althaea officinalis	I	1
Number of samples	20	
Number of species / sample	8.2 (4-17)	

Haddiscoe Island close to Breydon Water, and is often associated with poorly drained ronds which are highly saline as a result of evaporation of trapped river water. The mean salinity of the river water at the northernmost end of Haddiscoe Island between 1988 and 1991 was 8 g/l Cl^- This is more than ten times the limit of salt-tolerance of the salt-water biotype of *Phragmites australis* (0.73 g/l Cl^-) (Ranwell, 1992).

End-group 3 describes the short sward of saltmarsh vegetation which covers the front of the ronds up to 15km from the sea. It is dominated by common saltmarsh-grass *Puccinellia maritima* with abundant sea plantain *Plantago maritima*, sea aster *Aster tripolium* and greater sea spurrey *Spergularia media*, and is grazed by wildfowl at some locations. Tall tussocks of sea rush *Juncus maritimus* with a range of halophytes (end-group 4) occur among the saltmarsh sward, and are invariably avoided by grazing animals.

Reed is still harvested on some ronds between about 16 and 23km upstream on the Bure, Waveney and Yare. End-group 9 describes managed reedswamp which was cut in the previous year, and is dominated by tall reed (1.5 to 2.5m)

with a sparse understorey of halophytes in the more brackish reaches, and occasional tall herbs such as purple loosestrife *Lythrum salicaria* and marsh sowthistle *Sonchus palustris* where the inundating waters are fresher. There are also a number of ronds on all three rivers between 21 and 23km from the sea, where reed cutting has been abandoned. In the absence of management, a more diverse community has developed with an understorey of creeping bent *Agrostis stolonifera* which is co-dominant with *Phragmites australis* (end-group 10). Reed height is also less than in the managed reedswamp (1 to 1.5m).

The TWINSPAN classification characterized three communities which comprise the freshwater fen vegetation on ronds greater than 22km from the sea and up to the limit of the survey area. Two are *Phragmites*-dominated (end-groups 8 and 11), and one *Glyceria*-dominated (end-group 7). TWINSPAN separated end-group 8 from end-group 11 by the co-dominance of greater pond sedge *Carex riparia* with *Phragmites australis* and the higher frequency of yellow iris *Iris pseudacorus*. However, the two plant communities were not distinguished in the field and the species diversity (approximately 8 species per sample) is identical. They also occur together on wide ronds (>10m) on the Waveney and Yare, but only end-group 11 is found on the Bure and Thurne where the upstream ronds are generally less than 10m wide. There are no known differences in previous or current management which may have influenced the vegetation, but the presence of common couch *Elymus repens*, creeping thistle *Cirsium arvense*, false oat grass *Arrhenatherum elatius*, bristly ox-tongue *Picris echioides* and shrub and tree seedlings in end-group 11 suggests that some upstream ronds may be drier than others, which allows these species to invade the fen vegetation. Rond height, and thus the frequency and duration of inundation by river water, may vary as a result of natural topographical differences in marsh levels when the rivers were embanked, or may have been artificially elevated by the deposition of river dredgings. End-group 7 is characterized by the dominance of sweet reed-grass *Glyceria maxima* and occurs on ronds on the upstream, freshwater reaches of the Waveney and Bure only. The vegetation is species-poor due to the heavy litter layer of *Glyceria maxima* which may be up to 30cm deep, and prevents the growth of other species. This community is invariably located on the front of ronds greater than 10m wide, and may extend to about half the total rond width.

Two non-*Phragmites* swamp communities also occur on the ronds in the middle

reaches. End-group 5 describes relatively species-rich vegetation in which *Agrostis stolonifera* is co-dominant with *Carex riparia* and associated with a range of wetland plants including several tolerant of brackish conditions (brookweed *Samolus valerandii*, wild celery *Apium graveolens*, parsley water dropwort *Oenanthe lachenalii*). This community occurs on lower, wetter ronds on both the Waveney and Yare and is often grazed by cattle or feral geese. In contrast, end-group 6 docs not contain *Agrostis stolonifera*, only occurs on the River Yare and is not grazed. *Carex riparia, Glyceria maxima* and *Phalaris arundinaceae* are abundant but there are few salt-tolerant species. This community occurs on lower, wetter ronds on both the Waveney and Yare and is often grazed by cattle or feral geese. In contrast, end-group 6 does not contain *Agrostis stolonifera*, only occurs on the River Yare and is not grazed. *Carex riparia, Glyceria maxima* and *Phalaris arundinaceae* are abundant but there are few salt-tolerant species.

Affinity to the National Vegetation Classification (NVC)

The rond vegetation showed a broad fit to the NVC, but no close affinities to individual NVC communities, with similarity coefficients ranging from about 45 to 62%. The *Puccinellia maritima* salt-marsh vegetation (end-group 3) is most similar to the **SM13** *Puccinellia maritima* low to mid salt-marsh community, and the depauperate reedswamp with *Juncus gerardii* understorey (end-group 2) shows affinity to **SM16 sub-community a** which is dominated by *Juncus gerardii* and typical of mid to upper salt-marsh. Both are widespread nationally. The sea rush stands (end-group 4) are most closely matched to the **SM15** *Juncus maritimus – Triglochin maritima* saltmarsh which occurs on mid to upper saltmarsh and is frequcnt in south-east England. It is also clear that the fringing sea couch vegetation of the lower reaches of the rivers corresponds to the **SM24** *Elymus pycnanthus* drift-line and upper salt-marsh community which is also most abundant in south-cast England.

The brackish reedswamp vegetation described by end-groups 1, 2, 9 and 10 show affinity to the **S4 sub-community d** *Phragmites australis* swamp which is widesprcad nationally in brackish water or on rarely inundated upper salt-marsh. The *Agrostis stolonifera* swamp (end-group 5) is not represented in the NVC, but the vegetation shares a similar rangc of associate specics to thc NVC **S4 sub-community b** which is widespread in mcsotrophic to cutrophic flood-plain fens. Rond vegetation with abundant *Carex riparia* (end–group 6) shows

affinity to the **S6** *Carex riparia* swamp community which is also characteristic of eutrophic standing or slow-moving water in agricultural lowlands. Where this vegetation is grazed, *Agrostis stolonifera* may become dominant, and end-group 5 may represent an *Agrostis stolonifera*-dominated sub-community of **S6.** Eutrophic conditions, especially high phosphate, favour *Glyceria maxima* as in the **S5** *Glyceria*-dominated community. End-groups 6 and 7 show some similarity to **S5,** and the occurrence of mono-specific stands of *Glyceria* on the fore to mid-rond may be due to more frequent inundation of this part of the rond by nutrient-rich river water.

The freshwater fen vegetation types described by end-groups 8 and 11 are similar to the moderately and highly eutrophic fen vegetation characterized by **S25** and **S26** fen communities respectively, which are typically species-poor, and occur on winter-flooding lowlands and disturbed flood plains.

Nationally scarce plant species

Four nationally scarce wetland species were recorded on the ronds in 1992. Marsh sowthistle *Sonchus palustris* was abundant on all the rivers upstream of the boundary between brackish and freshwater (Figures 1, 2 and 3), and the ronds constitute a major stronghold for this species in The Broads. Marshmallow *Althaea officinalis* was frequently found growing amongst reed on slighty elevated, drier parts of the ronds (usually at the river edge) along the brackish reaches of all the rivers. Golden dock *Rumex maritimus* was locally abundant on recently deposited spoil on low-lying muddy ronds on the Waveney and Yare. The single record of tasteless water-pepper *Persicaria laxiflora* was amongst swamp vegetation on the ronds at Hassingham on the Yare.

Discussion

The ronds exhibit the more natural vegetation and habitats that would have existed in the floodplains before embankment of the rivers and drainage of the marshes. In total they support about 54ha of salt-marsh, 165ha of brackish reedbed and 75ha of fen, and contribute to the diversity of The Broads nature conservation resource. The extent of reedbed communities is especially important in the regional context.

The major cause of vegetation change on the ronds is saline intrusion in the rivers, often associated with impeded drainage and low rainfall, which results in

Poor reed growth and an expansion of halophytic plants. Cessation in reed cutting on many ronds has also been accompanied by the development of more herb-rich brackish *Phragmites*-dominated communities. These changes are likely to be irreversible in the face of sea-level rise and lower fluvial flows. Further degradation of the rond vegetation through spoil dumping should not occur, since this is now recognised as an unacceptable practice. However, loss of rond area due to boat wash and tidal scour is a serious problem, and the current mean erosion rate is estimated to be about 0.5m per year (Environment Agency data). The current strategy for flood alleviation in The Broads is for 'soft', sustainable engineering options which involve set-back of the floodbank and the creation of new ronds in preference to steel piling of the river banks. This approach could lead to significant environmental benefits, and this study of the existing rond vegetation should be valuable in setting objectives for rond creation and enhancement.

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WILDLIFE 2000

STUDIES ON THE RONDS OF THE RIVER WAVENEY

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Introduction

The upper clay in the Bure Valley is thought to correspond to deposits of Roman age in the Fens (Jennings & Lambert, 1953) and is covered at Horning with about 1m of peat. Examination of the clay just downstream of Horning Waterworks showed it to contain a sparse but interesting diatom flora.. Four species of large marine diatoms had also been found in clay of this age at Woodbastwick Fen near Horning Ferry and opposite St Bennet's Abbey by Macfadyan in Jennings (1952).

In the hope of finding similar conditions in the estuary of the present day a study was made of the diatoms and deposits on the river margins along the Waveney. No corresponding deposit was found.

The Ronds are areas enclosed between the relatively straight flood bank and the meanders of the river. They are mostly dominated by reed (*Phragmites australis*) although at Wicker Well reed sweet-grass (*Glyceria maxima*) dominates the ronds and is grazed by cattle.

The wavelength of the meanders decreases gradually as we pass up the estuary. At Breydon it is about 2km and at Oulton Dyke 1.5km. Actual figures, (mean of 3 meanders) are 1.96km, 1.66 km, 1.53km and 1.43km. The floodwalls make a corridor of about 140m width and the river is about 50m width. The river snakes between the flood banks so that the 90m width of rond is divided alternately betwen one bank and the other. In the Belton area the ronds are rather wider and have a few substantial pools on them. It is conceivable that these pools are old workings for river mud which was used at the cement works at Burgh Castle

Method

Samples were collected by dipping a one litre bottle about 0.5m below river surface (Dip), by collecting handfulls of leaf litter (Litter), by scraping the surface of the mud with a plastic card (Mud). Plastic card allowed a very thin layer, about 1mm, to be sampled and returned to the lab in a plastic bag. On arrival at the laboratory the sample was moistened with water from the site and left in a Petrie dish covered with a double layer of fine nylon material the upper layer being removed later and squeezed out to obtain the diatoms. As it was felt that this method excluded dead diatom frustules and non-motile diatoms, slides were made by gently stroking the diatoms off the surface of the mud in the Petrie dish using a squirrel hair paint brush. With some practice this proved quite successful. Samples of the subsurface mud were taken using a syringe with the bottom of the barrel cut off. This made a small and very portable piston corer, yielding a 30mm diameter core about 80mm long.

The ronds were examined in detail at four points: Belton, St Olaves, Herringfleet and Wicker Well.

To ensure that the Horning sequence was not in material other than on the bare mud surface, diatom collections were made in the leaf litter, in pools on the rond and, in the case of St Olaves a small core was taken out to examine the

nature of sediments in the recent past. Although these samples showed some difference from the mud surface diatoms there was again no comparison with the Horning clay diatoms.

To judge what percentage of marine and brackish diatoms occurred in samples at various localities each taxon was classified by recourse to Hartley et al. (1996) as marine brackish or freshwater. For each taxon the percentage was allocated to marine or brackish and the percentages summated. A particular problem with this application is the diatom *Navicula gregaria*, which can be freshwater, brackish or marine and occurs abundantly at all locations.

Belton ronds

The reed in this area is sparse, leaving bare mud between the haulms. Reed height varies, being highest near the river and on the flood bank at the back of the rond. The mud is firm but covered with 5mm to 10mm of liquid mud mixed

with reed leaf litter. In the very low parts in the centre of the bed the reed is replaced by grass. Water in a streamlet leaving the rond was 8,800 mg/l Cl^- In the centre of the rond diatoms are associated with reed leaves in the mud

Saint Olaves ronds

The area studied was about one mile downstream of St Olaves Bridge on the right bank of the River Waveney at TM 448998 where the power lines cross the river.The rond here is 110m wide In January 1993 water lying in pools on the rond had chloride levels between 5000 mg/l Cl^- and 6500 mg/l in a larger pool. Again reed heights varied from 2.5m at the floodbank to 1 m on the open rond. Towards the pool, which was 60m from the floodbank, the reed decreased to 0.6 m in height, the haulms were widely spaced and mostly sterile.

Herringfleet

By the smock mill at Heringfleet TM 465977 the rond is 50m wide and thickly grown with tall reed. There are no pools on the rond.

Wicker Well ronds

The rond at Wicker Well, just upsteam of the sluice TM 490959 is riverine. It is mostly covered with *Glyceria maxima* and is grazed by cattle. It has a narrow fringe of *Phragmites* along the river edge and a fringe of *Juncus* along the foot of the wall. There are no pools but the cattle leave deep footprints which contain water with a chloride level of 450 mg/l. This is less than the river at that point which, because it receives water from Oulton Broad on the ebb has a chloride level of about 600 mg/l.

Surge

An opportunity to study the effects of storm surge on the ronds arose over the weekend of 19-21 February 1993. There was an unusually high tide on the Friday afternoon. At 4 pm on that day (19.2.93) the chloride level in the river at St Olaves with the ebb just started was 11,700 mg/l Cl^-, rather more than half sea water.

On the "Power Line" rond, 1.2km downstream of St Olaves Bridge, on the right bank, water had been over the rond, refilling the pools, but with the departure of the surge tide there was no water left on the rond itself. The chlorides were Pool 13,400 mg/l, ditch on rond 12,300 mg/l and water flowing from the rond

east of the mill (800m downsteam of St Olaves Bridge) 13,300 mg/l. Evidently the flooding of the rond area took place at the peak of the surge.

The surge of 21 February was more dramatic. Flood warnings sounded at 6.20 am and parts of Gorleston and Haddiscoe were evacuated. The Acle road was closed as a precaution. High water was at 9 am at Gorleston. At St Olaves a fall in level was noticed at 11.15 am but the tide continued to run in very strongly. Chlorides were 16,900 mg/l and the turbidity of the water was 53 STU. In the laboratory the clearing of the turbid water was studied to give some indication of the rate of deposition from surge tide water onto the ronds.

The following morning there was still 50mm of water lying on the rond with a chloride value of 14,600 mg/l. The Pool had increased its chloride level to 15,000 mg/l

A slide made from the suspended matter in the river showed its diatoms to differ from those on the ronds. The following exceded 5% of the total diatoms in a Dip sample:-

Thalassiosira nana 25%
Cymatosira belgica 18%
Rhaphoneis minutissima 16%
Paralia sulcata 8%

Quite a percentage of diatom frustules in the rond samples was marine. At St Olaves as high as one third of the frustules counted were classified by Hartley *et al.* (1996) as marine.

Results

Details of diatoms in the Horning Clay are shown in Appendix 1. Whilst Table 1 compares the rond mud samples along the river and Table 2 compares various samples on the St Olaves Rond

Discussion

The large percentage of marine diatoms indicates that the origin of some of the sediments on the ronds is from the sea. It could be argued that these are largely littoral marine species and probably have their origin in the lower part of the estuary. However some are typical of the marine phytoplankton of the

North Sea off Yarmouth.

The salt water on the ronds has its origin in high tides. The diatoms, on the other hand, are primarily brackish water diatoms which are normal inhabitants of the ronds. The marine diatoms present on the ronds do not appear to originate from the turbidity at the peak of the surge. Movement of silt within the river appears to be complex. It is possible that surge tides, with their higher velocities, lift the mobile mud layer at the bottom of the river and this is deposited on the ronds early in the flooding of the rond.

The estuarine clay at Horning contained ten taxa, only one of which was brackish. It was dominated by the freshwater mud diatom *Pinnularia viridis* and the freshwater epiphyte *Epithemia turgida*. This suggests that it was a lagoon adjacent to the estuary, not in contact with the main area to the south which, according to Macfadyan contained some large marine diatoms.

The relation between diatoms in the various samples at St Olaves is interesting, (Table II) especially the relation of various habitats to the diatoms found in the core. Some of the material, like *Achnanthes delicatissima* and *Navicula perminuta* had its origin in leaf litter, while *Amphora coffeaeformis* had its origin in the pond sample, probably epiphytes on the small plants in the pond. *Navicula gregaria* was ubiquitous and came from both the leaf and pond samples into the core. *Navicula salinarum* was only found in the core and probably represents some higher salinity situation.

Comparison of the plankton material in the river with the core shows how little of the normal phytoplankton of the river got into the rond sediments. Only 9 of the 67 taxa listed in Table II were in fact common to both the plankton and the core.

Conclusions

Although no similar deposit to the Horning Clay was found in the present day sediments along the river these sediments were shown to be one of the best localities for brackish water diatoms in Norfolk. The ronds are worthy of conservation for a number of reasons, but such conservation should not involve a great change from the present regime so that the population of brackish water diatoms is preserved.

It is hoped that someone will investigate the status of diatoms in the Horning Clay, certainly within the nature reserves which have been established in that part of the Bure valley. The clay is only about 1 metre below the surface, so that it is easy to sample, even with trial pits

Table 1. Percentage of each diatom taxon found on mud surface at four ronds along River Waveney

	Belton	St Olaves	Herringfleet	Wicker Well
Km from harbour mouth	12	17.5	20.3	24
Achnanthes sp	1			
Achnanthes delicatula f b		0.5		1
Achnanthes minutissima f				1
Actinoptychus senarius m	1			
Amphiprora paludosa m		5		
Amphora coffeaeformis mb	7	10		
Berkeleya rutilans m			1	1
Biddulphia alternans m	4			
Campylosira cymbelifmis m				2
Cyclotella striata fb	1			
Cylindrotheca gracilis bm			1	1
Denticula tenuis f				1
Diploneis didyma m	15			
Falacia pygmaea mbf	10	4		
Frustulia rhomboides f			1	
Gyrosigma acuminatum bf				2
Gyrosigma scalproides m			2	
Luticola cohnii bf				2
Navicula capitatoradiata fb				2
Navicula cincta f				1

Navicula digitoradiata bm		3.5	5	2
Navicula gregaria fbm	40	55.5	17	10
Navicula halophila b		0.5		
Navicula peregrina bm		1		
Navicula perminuta	4	0.5		
Nitzschia sp	4		1	4
Nitzschia amphibia f				1
Nitzschia clausii f			0.5	
Nitzschia dissipata f	2		12.5	8
Nitzschia dubia bf			1.5	1
Nitzschia frustulum bf			0.5	
Nitzschia palea f			1	
Nitzschia paleacea f				7
Nitzschia sigma b		7.5	27.5	4
Paralia sulcata bm			0.5	1
Plagiogramma leve m				4
Pleurosigma angulatum b		6		
Raphoneis minutissima m	7			6
Stephanodiscus minutulus f				4
Synedra ulna f				2
Surirella brebissonii f		1	4.5	1
Thalassiosira eccentrica m	1			
Thalassiosira incerta m				1
Thalassiosira nana				7
Tryblionella acuminata bf	1			4
Tryblionella constricta m				2
Tryblionella levidensis m	2			
Percent marine	**23.3**	**33.74**	**14.07**	**23.33**
Percent brackish	**20.66**	**43**	**40.07**	**17.83**

Note: The lower case letters after each name represent freshwater, brackish and marine. They are obtained from Hartley *et al* (1996)

Table 2. Percentage of each diatom taxon found in various lacalities at St Olaves rond

	River Plankton	Core	Leaves on marsh	Pond
Achnanthes delicatula		13.5	20	1
Achnanthes minutissima	5.5			
Actinocyclus normanii	3			
Amphiprora costata	2			
Amphiprora paludosa			2	
Amphora coffeaeformis		22.5		13
Amphora ovalis	1			
Cocconeis placentula	8	1.5		
Cyclotella meneghiniana	10			
Cylindrotheca gracilis			0.5	
Cymatosira belgica	0.5		1	
Diploneis sp		0.5		
Diploneis interrupta		0.5		
Diploneis smithii		2.5		
Epithemia turgida	0.5			
Falacia pygmaea		5.5		4
Fragilaria capucina	16		0.5	
Fragilaria elliptica		1		
Gomphonema parvulum	0.5			
Gyrosigma attenuatum	0.5			
Luticola mutica	0.5			
Melosira varians	6			
Navicula sp		0.5		
Navicula cincta		0.5	0.5	
Navicula digitoradiata	0.5	2		2
Navicula gregaria	0.5	12	39.5	45

Navicula peregrina		4	1.5	1
Navicula perminuta		7	16.5	
Navicula radiosa	4.5			
Navicula reinhardtii	0.5			
Navicula rhynchocephala		0.5	4	
Navicula phyllepta	0.5	4	4	22
Navicula salinarum		5.5		
Nitzschia sp	1	8.5	1	
Nitzschia amphibia	1			
Nitzschia dissipata	0.5			
Nitzschia dubia	1			
Nitzschia filiformis	1			
Nitzschia frustulum	0.5		0.5	
Nitzschia gracilis	0.5			
Nitzschia palea			0.5	3
Nitzschia sigma	1.5	0.5		6
Nitzschia vitraea	2			
Odontella sp.		0.5		
Paralia sulcata	0.5			
Plagiogramma leve			2	
Planothidium lanceolata	1.5			
Pleurosigma angulatum		2		
Raphoneis minutissima	1	0.5		
Rhoicosphenia curvata	4			
Skeletonema subsalsum	4			
Stauroneis sp		1		
Stephanodiscus hantzschii	3.5			
Synedra ulna	6			
Surirella brebissonii	1			1
Tabularia fasciculata	1.5			

Thalassionema sp			0.5	
Thalassiosira sp				1
Thalassiosira bramaputrae	1			
Thalassiosira nana	3	1.5	3.5	
Tryblionella acuminata	1			
Tryblionella apiculata			1	

Appendix 1

Diatoms in estuarine clay on Seven Acre Marsh, below Horning Pumping Station TG 360162

Caloneis silicula	*Campylodiscus hibernicus*
Cymbella	*Diploneis elliptica*
Diploneis smithii	*Diploneis interrupta*
Epithemia muelleri	*Epithemia turgida*
Pinnularia	*Pinnularia viridis*

Acknowledgements

I am grateful to the members of the University of East Anglia Diatom Group for looking at some of the slides

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RARE PLANT BUG DISCOVERY

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Whilst clearing some scrub at Buxton Heath on Saturday 17th October 1998, Group member Don Kernott discovered an unusal bug in the leaf litter. I was summoned to take a couple of photographs of what appeared to be either a froghopper or a leaf hopper. We consulted our reference guides, but the illustrated species did not appear to include our specimen.

Once my film was processed, I sent the photographs of the bug to Ken Durrant, hoping that he could identify our mystery insect. Ken Durrant became quite excited about the find. He identified it as *Ledra aurita* (L.), the Eared Leafhopper, of the Cicadomorpha. There have been only two previous records relating to this insect in Norfolk, from Ringland (7th August 1876) and Fersfield, near Diss (7th September 1963).

The Buxton specimen was a fairly large, approximately 15mm in length, very flat and with a mottled grey colouration which camouflages it when on lichen covered bark. The pronotum (top of the thorax) was raised on either side, and represented raised longitudinal wings. The hind tibia was very flattened like a knife blade.

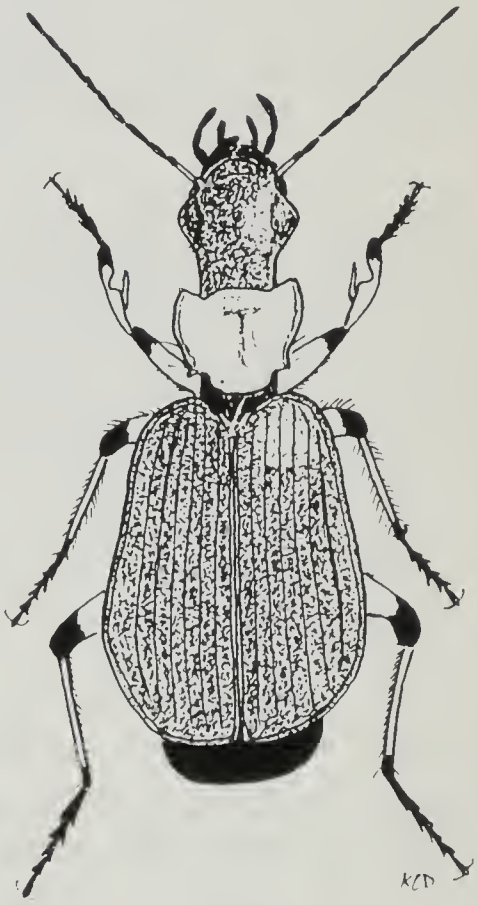
The species is the only European member of its group and was noted by Edwards (1896) as being widely distributed but uncommon in Norfolk. Recent publications show that the insect can be found in Southern and Central England. It should be looked for on its food plants; oak and alder.

Acknowledgements
I would like to thank Ken Durrant for his help with identification and Don Kernott for his keen eyesight, without which this rarity may not have been documented.

Miscellaneous observation

***Lebia cyanocephala* L. A rare find**: At one of our council meetings last September our chairman David Paull produced a film case in which he said was a very pretty beetle. "What is this"? he enquired.

When I saw the insect I realized it was a *Lebia* but which one? The five species of this group recorded in Britain are classed as rare or extremely rare. Most coleopterists never see one in a lifetime. Being southern European these islands are classed as being at the extreme northern limit of their natural territory. They have been bred here at odd times but have been very local and have not survived for long, possibly arriving as this one had in a consignment of fruit.



This specimen was 7.5mm in length with reddish-orange femurs and tibias with black apical areas. The thorax and first joint of the antenna was also reddish-orange. The head and elytra (wing cases) were bluish-black, the scutellum is black, indeed a very pretty beetle. They are nocturnal in habit feeding on the larvae of other insects and aphids. Their own larvae are parasites in the pupae of leaf beetles.

David Paull had been preparing to eat a nectarine when the beetle fell onto the table from the fruit he was handling. A very lucky find indeed.

Ken Durrant

LOPHOCOLEA SEMITERES (LEHM.) MITT. AND *HENNEDIELLA MACROPHYLLA* (R. BR. ter.) PARIS, NEW TO NORFOLK.

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Recently two alien species of bryophyte have been recognised in West Norfolk. The liverwort *Lophocolea semiteres* (southern crestwort) has clearly been present for some time, since it occurs over areas of many hectares at several places near King's Lynn. The moss *Hennediella macrophylla* (short pottia) may be a more recent immigrant since, as yet, it has only been found within King's Lynn itself, although it appears to be spreading within the town. Nomenclature follows Blockeel and Long (1998).

A. *Lophocolea semiteres* (Lehm.) Mitt.

Lophocolea semiteres is an alien species of liverwort, which is native in S. Africa, S. America, and Australasia. It was first found in Europe in the Scilly Isles (Paton 1965), and later in Argyll (Long 1982). In both these localities it is associated with botanic gardens; Long (1982) speculates that it was probably introduced independently, with the planting of exotic trees.

Subsequently it has been found both in the Netherlands and in Belgium. It appears to be fairly widely distributed in both countries (Stieperaere 1994; Gradstein & van Melick 1996). It has also been found recently in both East and West Suffolk.

It resembles two common species of native liverwort, *Lophocolea heterophylla* (Schrad.) Dumort., and *Chiloscyphus pallescens* (Ehrh. ex Hoffm.) Dumort. In practise, however, confusion is most likely with *Chiloscyphus*. Table 1 summarises the main differences between the three species. It is illustrated in Figure 1.

At present it is known from three localities in the county, all in West Norfolk (VC 28). However, it is to be expected elsewhere, and is liable to spread, like two other alien moss species present in Norfolk (*Campylopus introflexus* and *Orthodontium lineare*).

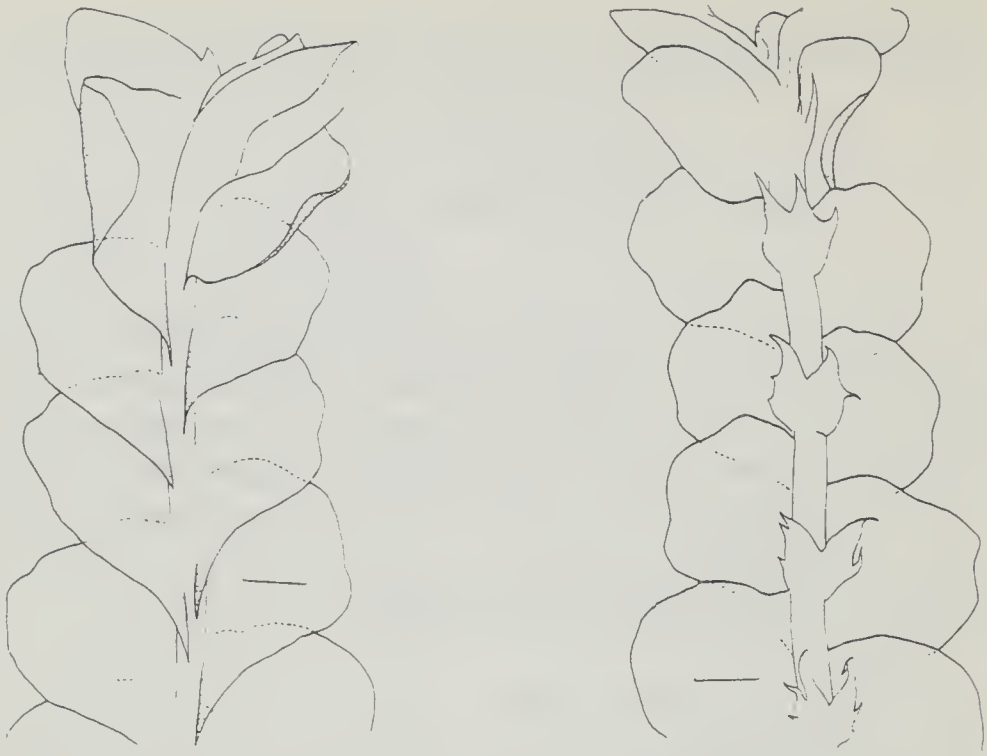

Figure 1. *Lophocolea semiteres* upper and lower surfaces.
Scale bar on leaves = 0.5cm

1. The Bawsey-Leziate area (TF670-185). *L. semiteres* occurs quite extensively in this area. As in its other known British and Continental localities it occurs in a range of slightly differing habitats, all of which are acid.

It occurs most prominently on the sandy sides of a rough track running through from Bawsey to Leziate. It occurs both as pure mats, and mixed with vascular plants. In places it is overgrowing mats of *Campylopus introflexus* – a good indication of its aggressive capacities as a coloniser.

It also occurs in adjacent acid grasslands, and in *Calluna* heath, where it is commonest by the sides of paths and on the edges of the actual heath areas themselves. The heath edges into birch / oak woodland, where, in clearings, it may occur in extensive prostrate mats. Most frequently, however, it is found along the sides of paths and tracks, growing on sandy or organic soils. Rarely, it occurs as an epiphyte at the base of birch trees. (Published accounts indicate

that this, as well as rotting wood, is a favoured habitat elsewhere).

Characters	L. heterophylla	L .semiteres	C .pallescens
Leaves	Markedly diomorphic. Lower leaves (& sometimes branch leaves) bilobed with acute to acuminate lobes. Mature leaves subimbricate / imbricate, rarely distant, with apex truncate, obtuse or emarginate, rarely rounded. Widest just above base. Spreading horizontally.	Bilobed on lower or depauperate stems, rarely toothed. Oblique triangular to oblique ovate in shape. Apex normally entire or emarginate. Widest at base. Imbricate, dorsally secund, spreading horizontally, or reflexed, especially when dry. Apical leaves erect and appressed.	Rounded to emarginate. Branch leaves sometimes bilobed. Distant to subimbricate
Gemmae	Rare - on tips of apical leaves. Unicellular, spherical, c 30µm	On leaf edges, rare, may devellop into a leafy stem before falling. Irregular multicellular. Brood branches also produced from ventral merophytes which have minute deeply bifid leaves with sharp lobes.	None reported
Underleaves (see Fig.2)	Bilobed to 1/2-2/3 with large tooth on each side. Lobes acuminate. Narrower than, or equal to, stem width. rarely connate with lateral leaves.	On well developed branches are large and broad - up to 2.5 x stem width; deeply divided into two lobes with well developed laciniae. Sometimes connate with leaves	Narrower than,or equal to stem width.
Sexuality	Paroicous (rarely auloicous). Normally abunantly fertiles.	Dioicous	Autoicous
Ecology	Tree boles (rotting wood/ rocks/ rarely on soil/ woods	Acid sandy soils/dry heaths/ oak-birch woodlands/ conifer plantations/ sandy roads and paths. Damp areas.	Stones/ tree roots soil in damp habitats/ streams and pools/ wet turf/ rotting logs

Table 1. major identification characteristics of *L.semiteres*

The plants at Bawsey are growing in an area of old sand workings: the associated vegetation appears to have regenerated naturally. The area is quite distant from any gardens, so how they got there must remain a mystery. However, they are clearly successful colonisers and competitors, and have colonised an area of at least 16 hectares.

The associated vascular plants include *Pteridium aquilinum, Betula* spp., *Pinus sylvestris, Calluna vulgaris, Carex arenaria* and *Rumex acetosella.*

The most commonly associated bryophyte species were *Campylopus introflexus* – itself an alien from the southern hemisphere, *Dicranum scoparium, Pohlia nutans, Polytrichum juniperinum, Ceratodon purpureus*, and *Brachythecium albicans.*

The earliest record for this plant, in this area, is from 1981, when it was mis-recorded as *Chiloscyphus pallescens.*

All of the plants examined seem to be female; perianths seem to occur particularly round the edge of colonies, on older, semi-decayed / dying stems. This suggests that perianths develop at a late stage and are then overgrown, making them less conspicuous, unless searched for carefully.

2. Blackborough End (TF681-144). At this locality the plant has been known since at least 1988, when it too was misidentified as *Chiloscyphus pallescens.* This locality, which is an area of old sand and gravel workings, is interesting since it is decidedly damp. It occurs amongst *Juncus* and *Typha;* associated species of bryophyte include *Aulacomnium palustre; Blasia pusilla; Campylopus introflexus; Pohlia nutans; Polytrichum juniperinum; Riccardia chamedryfolia* and *Lophozia capitata*

L. semiteres does not appear to have been recorded from such a damp habitat elsewhere in Europe, although it occurs in 'swamps' in Australia (Scott, 1985).

On the drier steep sides of the pit it occurs with species such as *Atrichum undulatum, Lophozia excisa, Nardia scalaris, Polytrichum juniperinum, Pogonatum aloides,* etc.

3. Fordham Fen (TL612-992). Fordham Fen lies south of Downham Market. *L. semiteres,* which was first recorded from this site (as *Chiloscyphus pallescens*) in 1982, occurs extensively in a small conifer plantation, both on needle litter, and also on banks and tree bases around the edge of the plantation.

Associated species on the needle litter floor included *Eurhynchium praelongum*

Plagiothecium curvifolium, and *P. undulatum*.

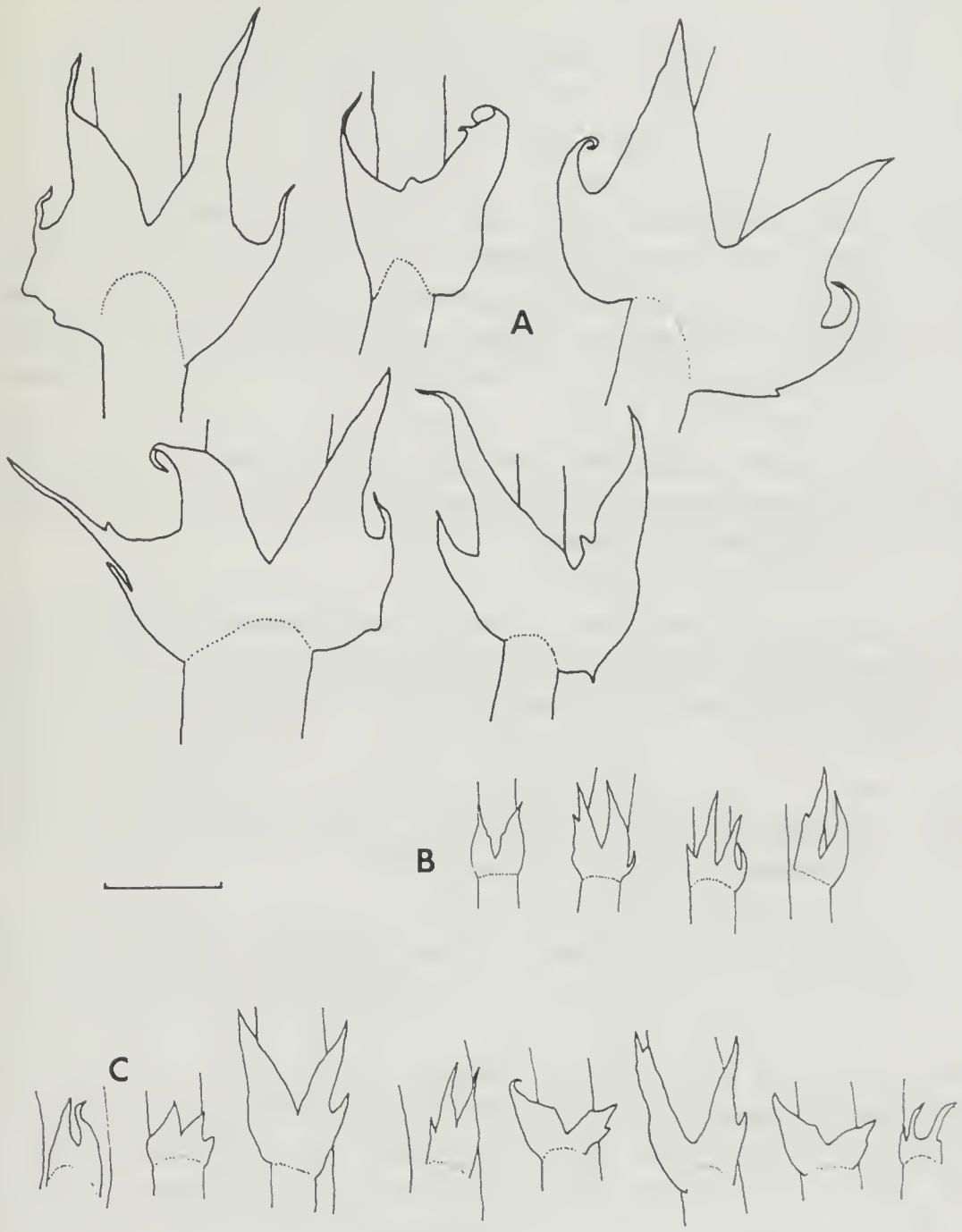

Figure 2. Comparisons between underleaves of (A) *Lophocolea semiteres*, (B) *Lophocolea heterophylla* and (C) *Chiloscyphus pallescens*. All to same scale. Bar = 0.5cm

Discussion

In Australia Scott (1985) notes that *L. semiteres* is especially common on fallen logs, but also occurs as an epiphyte, on rock and soil in dry or wet forest, dune scrub, swamps, and even city parks. Given the ability to occur in such a wide range of habitats *L. semiteres* clearly has the ability to colonise still further within the U.K.

Elsewhere in Britain this plant seems to occur chiefly on rotten logs; tree bases; peaty banks and tracks; paths in heathy areas; fixed, non-basic dunes etc. (Paton 1965; Long 1982). The Norfolk localities so far observed differ in that it occurs only rarely on tree bases or rotting wood. Some of the sites on which it grows are 'peaty' [compacted bracken and leaf litter], and in such habitats it is fairly shaded. However, it also seems to grow happily on open sands with some organic content, often where there are gentle slopes, and also in adjacent Callunetum. It also occurs in *Carex arenaria* communities (as in W. Suffolk) though it is not abundant in this habitat.

Stieperarae *et al.* (1997) note that *L. semiteres* occurs in similar habitats to two other southern aliens, *Orthodontium lineare* and *Campylopus introflexus*. They make the observation that it is not unlikely that *L. semiteres* will spread in a similar fashion, though they do note that it has a more limited dissemination capability, due to the rarity of sporophyte production. They also predict that *L. semiteres*, having more effective local dispersion mechanisms (brood branches) is likely to out-compete the native *L. heterophylla*.

A more alarming possibility, however, is the possible effect that this plant may have on some of the rarer small leafy liverworts which occur in the county. Past accounts of some of these species seem to indicate that they were formerly commoner than they are today; the reasons for this decline are not known. Changes in land management, habitat modification through seral progression, and nitrification are possible causes. However, some suspicion rests on the invasive alien mosses *Campylopus introflexus* and *Orthodontium lineare*, which frequently grow in similar habitats, and are both vigorous and aggressive. As is *Lophocolea semiteres*.

Species which are vulnerable include *Nardia scalaris*, *Lepidozia reptans*, *Lophozia capitata*, etc.

Continental botanists (Stieperaere, Heylen, & Sollman. 1998) have already dubbed this plant a potential 'plague' species. They may well be right.

B. *Hennediella macrophylla* (R. Br. ter) Paris

This plant was first described in this country as a new species, *Tortula brevis* (Whitehouse & Newton (1988). It was subsequently recognised, by Blockeel (1990) as conspecific with *H. macrophylla*, which occurs in New Zealand and Tierra del Fuego,. (Ochyra & Matteri (1996) regard *H. macrophylla* as conspecific with *H. antarctica*, and have relegated it to synonymy with that species; however, Blockeel (pers. comm.) has expressed doubts as to the conspecifity of the two species. Accordingly the name *H. macrophylla* has been retained).

H. macrophylla is distinctive, even in the field, because, unlike other 'Tortulas' it has a border to the lower part of the leaf which can be clearly seen with a x20 hand lens; the leaf tip is also toothed. Sporophytes are not uncommon, and the short seta and long calyptra to the capsule are characteristic (Fig. 3). No trace has been seen of the gemmae described by Whitehouse and Newton (1988); curiously these are not mentioned either by Ochyra (1998). (Separation from *H. stanfordensis* is based on cell size differences, as well as on the shape of the leaf tip, which is much blunter in the latter species).

The distribution of this plant in Britain is quite restricted. It occurs in Northumberland and southern Scotland, associated largely with the Tweed basin; another cluster of stations occurs in the Thames basin (Sussex, Surrey, Essex, Hertfordshire, Middlesex, Berkshire and Bucks). An isolated occurrence between these two is in Derbyshire.

In March 1999 it was found in King's Lynn (VC28). It was first found as a small patch measuring only a few centimetres square, on compacted bare loamy soil, under a beech tree, in a small area of park situated beside the Gaywood river, adjacent to the Old Town Wall in Kettlewell Lane. It was subsequently searched for in 'The Walks', another area of urban park offering very similar habitat. Several small patches bearing sporophytes were located close to the margins of The Walks Rivulet. It was then found in considerable quantity on bare soil under trees at the southern edge of the park.

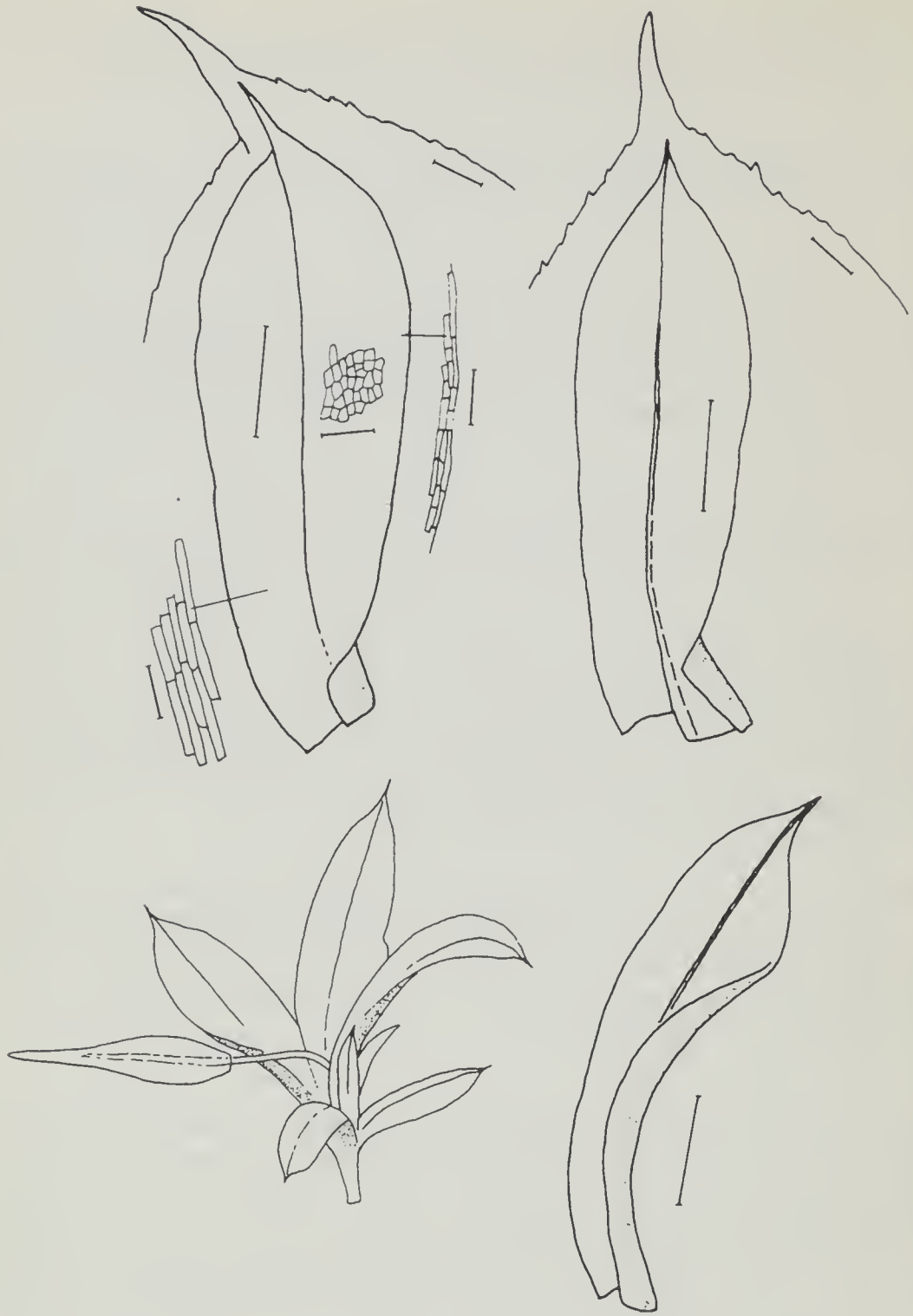

Figure 3. *Hennediella macrophylla*. Leaves all to same scale. Long scale bar = 0.5cm: cell details and leaf tip outlines – short scale bar = 0.1cm

A detailed search was then made of other suitable localities, and it was found at several others, all as small colonies, and all in the same sort of habitat, i.e. trampled earth, usually near tree roots, and often near water of some kind.

1. The St. James End of The Walks (TF6235-2040) – the main area of occurrence. Extensive colonies occur in this general area, and running alongside the Gaywood river, towards the town.
2. Kettlewell Lane (TF6235-2040) – only in small quantity.
3. Swaffham Belt (TF634-196) – in several places alongside the urban cyclepath, but only in small quantity.
4. Gaywood Park (TF639-202) – in very small quantity, near the entrance to the Council Nurseries.
5. Springwood (TF6465-2035) – in very small quantity.
6. All Saints' Church (TF6205-1958) – very sparse, by north-east corner of the church.

Associated species include *Pseudocrossidium hornschuchianum, Didymodon fallax, Rhynchostegium confertum, Eurhynchium praelongum, E. pumilum, Barbula convoluta & B. unguiculata. Hennediella* is reasonably conspicuous when forming monospecific patches, but is much easier to overlook when growing amongst other mosses.

Discussion

The initial discovery of the plant, in small patches, led to the assumption that it was a very recent immigrant. The extensive colonies at the southern edge of The Walks however, suggest that it has been around for rather longer. It appears to be spreading slowly outwards from this centre of distribution.

It is difficult to decide how this plant got here. Whitehouse (in Hill, Preston and Smith 1992) suggests that it is spread by water, human footwear and other animals' feet. Although most of the localities in Lynn are close to water they are all well above any recent flood level; spread by water itself therefore seems unlikely. They are, however, mostly in places that are much frequented by both humans and waterfowl, whose feet therefore seem the most likely methods of transmission. Dogs are also probably important, since many of the sites show considerable evidence of their presence. (Ochyra (1998) notes, of *H. antarctica*,

that it is closely associated with sites enriched by birds or elephant seals).

The much more restricted habitat requirements of this species mean that it is unlikely to spread as aggressively as *Lophocolea semiteres*, or to pose any threat to native species. In this it is similar to two other aliens which have been detected in Norfolk, *Riccia rhenana* (an aquatic liverwort) and *Didymodon (Trichostomopsis) umbrosus* (a plant found chiefly on damp brick walls).

It should be looked for in winter and spring, in habitats near water, where bare soil exists around tree roots since it dies back in summer.

Acknowledgements
Thanks are due to Mrs Rina Glover, for translations from Dutch; to Dr. Hermann Stieperaere for supplying literature, and helpful comments, and to Dr HLK Whitehouse, for confirming the identity of *Hennediella*. David Strauss was kind enough to proof read the manuscript, and to suggest useful changes.

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Miscellaneous observations

Return of *Erythromma najans* to Wheatfen. The Red-eyed Damselfly (*Erythromma najans* Hansemann) was last recorded at Wheatfen by E.T.Daniels in 1940. Whilst taking the small boat out into the Fen Channel I approached the now enhanced area of yellow water lilies (*Nuphar lutea*). The pads were prominent due to the low tide. My eyes were drawn to a much larger damselfly alighting on the pads which was then joined by many others.

The size was larger than the Blue-tailed Damselfly The other notable features were the maroon eyes and the aggressive behaviour. On my return I checked in the guide and I was able to verify that it was a male Red-eyed Damselfly. A return after over half a century. The decline may have been due to the loss of the white water lily (*Nyphaea alba*) in the 1950's.

A few days later females were also seen and many were mating over the lily pads. Reports have also now come to hand of the species returning to Rockland Broad.

David Nobbs,
The Ted Ellis Trust

WEATHER REPORT 1998

J.G. Hilton
Morley Research Centre, Morley, Wymondham NR18 9DB

1998 was the wettest (798.6mm) since 1960 and the dullest since 1994 (1476.8 hours). The mean temperature was equal to that of 1997.

January was the wettest for three years and the mildest for four. Sunshine was 18% above the long-term mean. The first 15 days were much milder than normal and 10^0C was exceeded on six days. This period was noticeably wet. The rest of the month was cooler than normal and mainly dry apart from two wet days.

February was the driest since 1959 and the mildest for seven years. Sunshine (148.8 hours) was the highest in our records, which began in 1925. The recording of 17.2^0C on the 14th was equal to the warmest February day in our records.

March was 1.9^0C above normal but was cooler than in March 1997. The month had less than half the sunshine hours recorded in February and rainfall was the highest for four years. Rain fell on every day until the 12th and it was exceptionally wet on the 6th (26.8mm).

April was the wettest since our records began in 1925, and the total was not exceeded in our library records which date back to 1888. Rain fell on 29 days. There were nine days with more than 5mm rainfall, and of these three had in excess of 10mm. It was the cloudiest since 1992.

May was the driest for seven years and the warmest since 1992. Sunshine was well above the long-term norm. Light showers were recorded during the first eight days, and dry weather then prevailed until the 26th.

June was much wetter than normal but not as wet as June 1997. It was the cloudiest since 1988 and the warmest for four years. Showery conditions prevailed for much of the month.

July was the dullest since 1978 with less sunshine than February. It was also the coolest for five years. The weather was cool and cloudy until the 18th but rose to 29°C on the 20th before falling back to near normal values. The last three days of the month were wet.

August was the coolest for five years but almost equal to the long-term average. It was slightly sunnier and drier than normal. A cool, cloudy but dry start gave way on the 4th to a period of warm weather but normal conditions returned on the 18th and cooler temperatures prevailed after the 22nd.

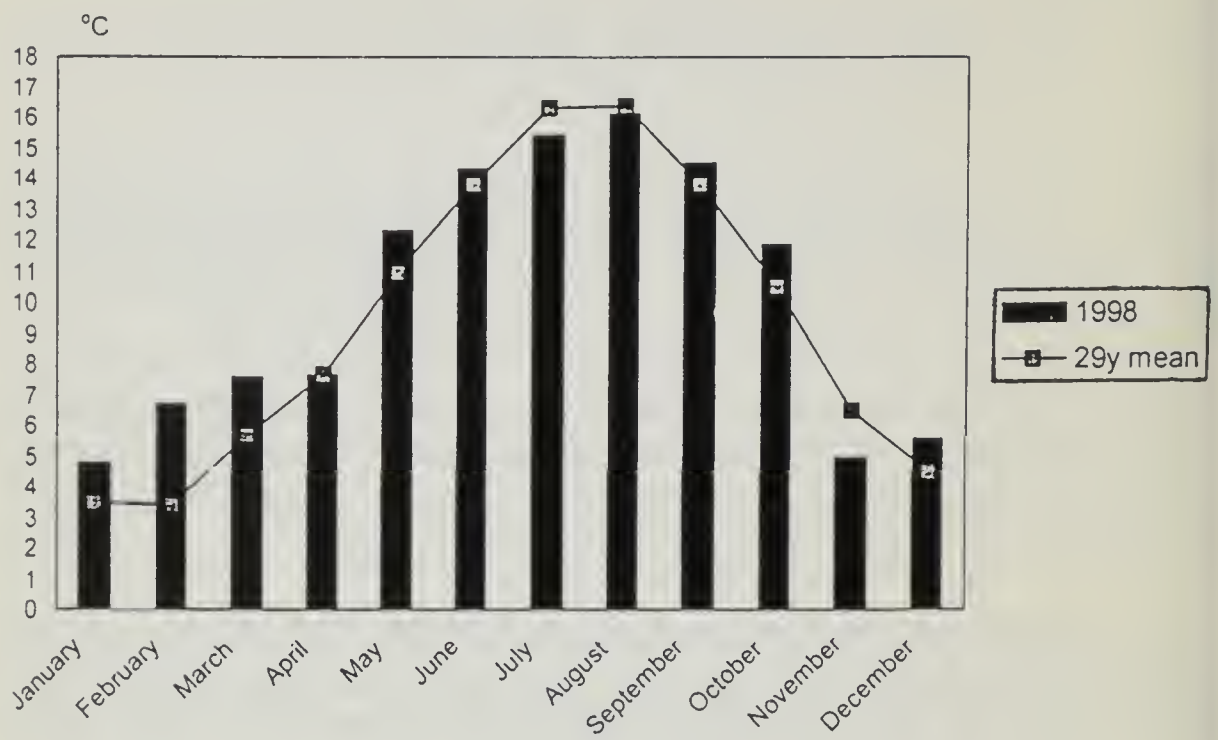
September was the warmest since 1989 owing mostly to the well above normal minimum temperatures. Rainfall was the highest for three years and the sunshine the lowest for four. For the first ten days minimum temperature recordings were well above normal as wet weather prevailed.

October was the wettest for five years, the mildest for three and the dullest since 1996. The first ten days were cooler than normal but the nights were mild. Rain fell on most days. Unsettled weather was recorded for the rest of the month. Heavy rain fell on many days.

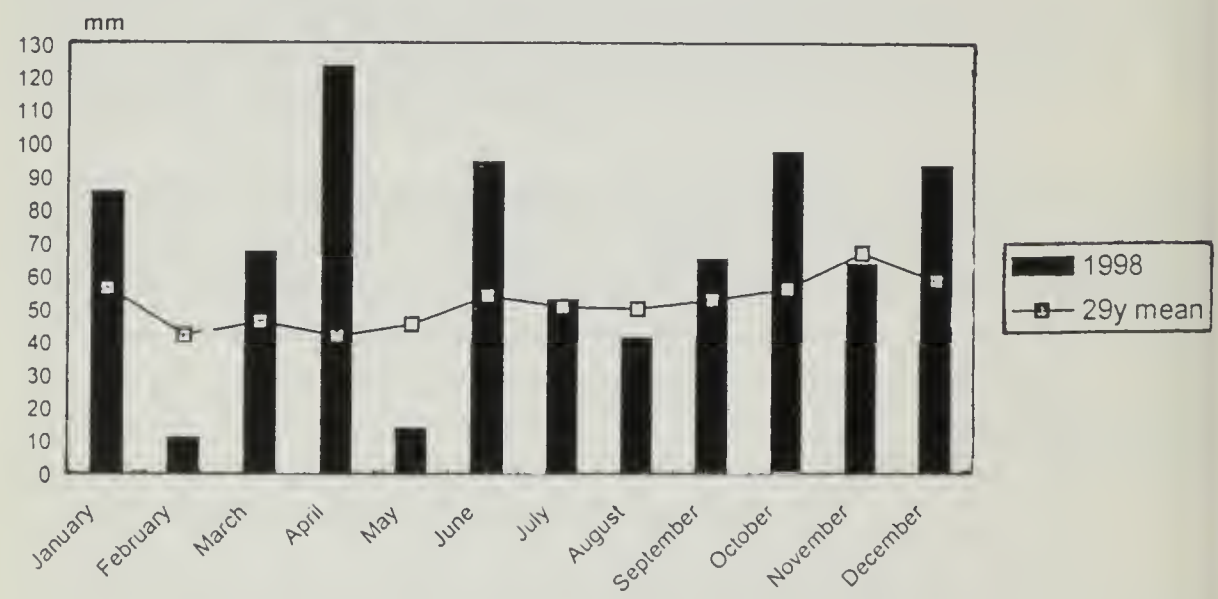
November was the coolest for five years. Rainfall was slightly less than normal but sunshine was the highest since 1989. Unsettled weather for the first eight days was followed by three sunny days. Cooler conditions were then recorded until the 25th but overcast and milder weather occurred during the last few days.

December was much wetter and milder than normal, but not as wet and mild as December 1997. Sunshine was slightly below normal. The first week was cold and showery, but mild weather was then recorded until the 18th. The temperature of 15.3°C on the 14th was the mildest December day in our records. Heavy rain fell at times and it was particularly wet from the 23rd to the 26th, and windy at times.

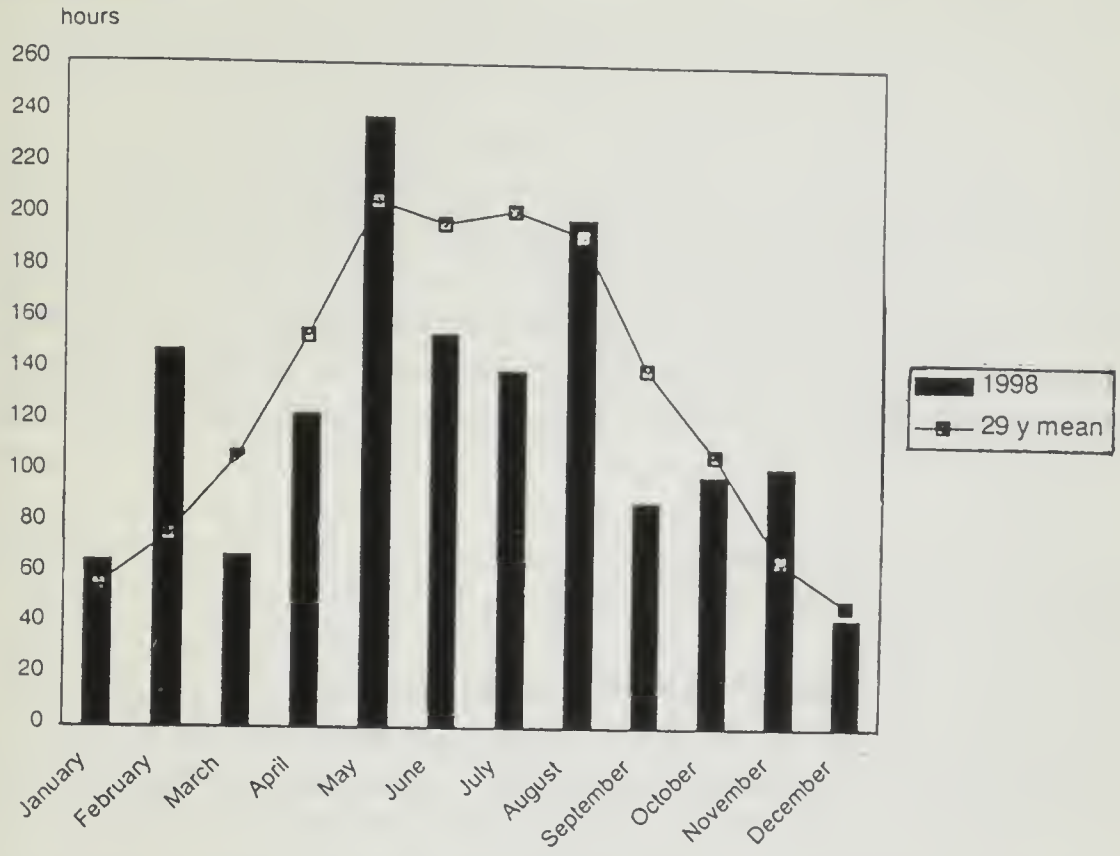
Mean Temperature



Total Rainfall



Total Sunshine



PLANT NOTES 1998 - OR PERHAPS MORE ACCURATELY, LOOKING AHEAD TO 1999 AND BEYOND.

Alec Bull.

By the time that you read this, you will already know that I have relinquished my post as East Norfolk Recorder after a period of 14 years. There were various reasons for this, one being that I have no intention of carrying on in the post until senile, but of handing over to someone younger who is a good botanist and, with the introduction of ever more sophisticated equipment, both locally and nationally, it is now imperative that the recorder has access to and is fully conversant with all the intricacies of the computer world. Bob Ellis arrived upon the botanical scene in East Norfolk five or six year ago, and has more than proved himself on both counts. One has only to look through the maps in our new County Flora to realise this. One can only hope that Bob will get as much support that I have had.

At the same time, I will still be carrying on with some of many practical things that are still to be done. Such a one is searching at a more leisurely pace than has been possible over the past few years for some of those plants which either have, or have not been found since Petch & Swann, or perhaps since the time of Nicholson's *Flora of 1914*. To give an example, Petch & Swann give under extinct species *Equisetum hyemale* (this is rough horsetail in Stace). "Very rare, perhaps extinct, marshy places." Last recorded from Ditchingham in E39 (*Flowering Plants of Harleston*) Swann's *Supplement* (1975) includes a West Norfolk record, a considerable colony still exant having been reported from Stibbard in 1974 by the farmer Mr R. Harmer and verified by E.A. Ellis. A further West Norfolk record has been found more recently by Miss D. Maxey at Shipdham.

I have had the good fortune to be lent a copy of *The Flowering Plants of Harleston and its District* published by the Rev. Galpin in 1888. The Ditchingham record must be regarded with suspicion as Galpin quotes the recorder as saying 'I think I have seen this at the west end of the Bath Hills at Ditchingham'. However, he also gives "Hedenham" and quotes Withering's *Arrangement of British Plants* of 1776-1816. Is this the best that East Norfolk can do? On January 28th 1999, I went to a lane near Morley St. Peter's Church and was able to confirm a colony stretching along a roadside hedge for some 20m where Shane Plant had spotted it three days earlier, growing at the back of a roadside nature reserve!

Of other plants on Swann's list of extinct species that we now know are alive and well, *Lycopodium clavatum* is still in the Sheringham area where it had last been recorded by W.H.Burrell in 1903. *Raphanus maritimus* can still be found in a few places around the north-east coast, and especially on the sea banks in the lower part of Breydon Water. *Pimpinella major* is a well established introduction at Wheatfen Broad, Surlingham, also the site for the only known and recently discovered colony of hemlock water dropwort, *Oenanthe crocata*. wayfaring tree, *Viburnum lantana* has been widely used in amenity plantings in recent years, but is believed to be native in one site in Gawdy Hall Great Wood near Harleston. There are probably a number of other examples that could be quoted. To re-find some of those plants that Swann recorded as being extinct would probably be beyond the realms of wishful thinking, such as *Holosteum umbellatum*, jagged chickweed, which was a plant of old walls and

thatched roofs and has not been recorded since 1887. Some, such as violet horned poppy, *Roemeria hybrida* were cornfield weeds and were probably early introductions.

But what about sea storksbill, *Erodium maritimum?* It was recorded by Kirby Trimmer (1866) from Mundesley. I have found musk storksbill *Erodium moschatum* there in recent years. Have they both occurred there? Or was K.T. wrong and his record should have been of *E. moschatum?* Or have I made a wrong identification? I think not, having found the plant a number of times in recent years. In 1996, a visiting Botanist cum Ecologist was doing surveys near the Bacton Gas Terminal and sent in a record for *Centaurium littorale*, seaside centaury, found by the cliff path between the Terminal and the path across to Paston. The following year a recording party found masses of common centaury, *C. erythraea*, but nothing else. Could it have been growing on a path up the face of the cliff from the beach and we failed to look for such a site? Was the visitor wrong? He came from the northwest where *Centaurium littorale* is not uncommon. We have no records in the East for upright chickweed, *Moenchia erecta* since Swann found it on Blakeney Point Petch recorded it from Salthouse Heath and Ted Ellis had it on Swannington Upgate Common and Bryants Heath, Felmingham. Has it really gone from all these places, none of which has been subjected to any particular disturbance in recent years. Oh yes! Though we have re-found hairy violet, *Viola hirta* at South Lopham Fen, and up on the clay near South Lopham village, and this was in East Norfolk by Grid Reference for the *Flora*, so far as the B.S.B.I. is concerned, these records are in West Norfolk as they only recognise the Watsonian boundary which is the 1 East line of longitude, which means that the South Lopham Fen record, near the path at the western end of the Fen, was only 200 metres from the V.C. Boundary. Surely it grows somewhere East of this?

One last thought for research in the East, though in that part of political Norfolk that lies in Watsonian V.C.25, East Suffolk. The Green brothers, authors of the *Atlas Flora of Somerset*, did a week's hard recording whilst on holiday here in 1995, and included two records of *Fumaria bastardii* which they were familiar with in Somerset, both from the Belton, Burgh Castle area. Swann has "Ranworth 1915, C.E.Salmon"only. We have quite a lot of tall ramping fumitory, *Fumaria muralis* ssp *boraei*. Stace states that *F. muralis*

has a large number of variants which make separation from *F. bastardii* often very difficult. Were the Greens right? Or were they deceived by *F. muralis* "forma *pseudobastardii*"? Perhaps someone would be brave enough to try and confirm *F. bastardii* for us.

One last thought. Is there any relatively young botanist out there who might have a genuine interest in learning the brambles? I do not suppose that my time for study of the genus is unlimited. It has taken me 30 years to be completely confident with the genus, but, like all students of the genus can still make the odd mistake. Is there anything still to be learned about Norfolk blackberries? Several more species were added to the county list in 1998 so yes, there is! If anyone is interested, I would be willing to give them tuition, but only on the understanding that they start their own herbarium as this is an essential tool in the study of the genus - a fully verified voucher collection. There are more than 80 recognised species in the county now. It would be nice to think that there would be someone willing to carry the interest along, rather than having to wait another 100 years before Norfolk has another resident batologist. The last was the Rev. E.F.Linton, and then only from 1879-1889.

West Norfolk Postscript – Gillian Beckett

In the west of the county, we have been working along much of the same lines. Certainly there is much more to be found by those with the necessary combination of eagle eyes and sufficient keenness to be prepared to search. In 1998, Stuart Fisher refound in West Norfolk two of the species Alec lists above, *Moenchia erecta*, upright chickweed at Snettisham and *Lycopodium clavatum*, Common Clubmoss at Bawsey as proof that this is so. Looking in old sites can be rewarding as long as the habitat has not changed too much and in fact it can save disappointment, for example, during our *Flora* survey we found *Trifolium ochroleucon*, sulphur clover, a rare plant in West Norfolk, near Mileham only to discover that it was in exactly the same site where Miss Maxey had first noted it in 1962. It had not been there on a regular basis so presumably came up from seed when the conditions were right, so one visit to search for a lost plant may not be enough. One of the most interesting plants which seems to be decreasing rapidly - or perhaps just failing to be spotted – is yellow-wort, *Blackstonia perfoliata*. This used to be quite frequent on the chalky boulder clays of south Norfolk and I remember seeing it on more than one N.N.N.S. outing in the late 1950s to 1960s. Now it is rare with only two

records from each half of the county. Even odder is the fact that the West Norfolk site was not known to Petch & Swann, but to Mark Rutterford, a Suffolk botanist, who described it in *Recollections of a Countryman* published posthumously by his son in 1992, describing 'hundreds of Yellow-wort; the whole plant is waxy-grey, with perfoliate leaves, growing on the solid chalk'. That superb site near Feltwell was not apparently known to Norfolk botanists until 1991 when it was spotted and reported by John Secker. It is large enough to spread into two tetrads so merits two spots in the Norfolk Flora's maps! So keep searching I certainly shall, and please send in interesting records, both old and new to keep the card index (and the computer) up to date.

A FLORA OF NORFOLK

By

Gillian Beckett

Alec Bull

Robin Stevenson

Although **Norfolk** is very much an agricultural county, it has a **wealth of wild places**. The plants of the **Broadland, Breckland** and the **North Norfolk coast** are well known to many botanists, but the teams of recorders working on this Flora has covered all parts of the county and made **many new discoveries**. The book is, however, not only for **botanists** but will be an important tool for **conservationists** and also the essential guide for anyone with a love of plants and the Norfolk countryside.

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